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INHERITANCE OF SMOOTH AWN AND DISEASE REACTION IN BARLEY CROSSES

Walter Herald Johnston
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University of Alberta,
Edmonton, Alberta.

April, 1933.

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The undersigned hereby certify that they have read and recommended to the Committee on Graduate Studies for acceptance a thesis on "Influence of growth and disease reaction in barley crosses," submitted by Walter Harold Johnston, B.A., B.Sc., in partial fulfillment of the requirements for the degree of Master of Science.

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INHERITANCE OF SMOOTH AWN AND DISEASE REACTION

FACULTY OF AGRICULTURE.

The undersigned hereby certify that they have read and recommend to the Committee on Graduate Studies for acceptance a thesis on "Inheritance of smooth awn and disease reaction in barley crosses," submitted by Walter Herald Johnston, B.A., B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

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Edmonton, Alberta
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INHERITANCE OF SMOOTH AWN AND DISEASE REACTION
IN BARLEY CROSSES.

W.H. Johnston

INTRODUCTION

The breeding of smooth awned barleys has received considerable attention in the last few years. The advantages possessed by this type of barley have been pointed out by Harlan (13) and need no further discussion. It is important that such a desirable character as smooth awn be associated with an equally desirable one, that of disease resistance. With the exception of the investigations of Hayes et.al. (17), and Griffee (12), practically no work regarding the breeding of smooth awned barleys for resistance to disease has been reported. This study was undertaken with the two-fold purpose of studying the relationships existing between smooth awn and reactions to the pathogens Ustilago hordei (Pers.) K.& S., Ustilago nuda (Jens.) K.& S., and Helminthosporium gramineum Rabh. and to determine if possible the mode of inheritance of these characters. Genetic data were also compiled on earliness and height of plant and length of rachilla hairs.

The breeding of smooth-skinned barflies has received considerable attention in the last few years. The advantages possessed by this type of barfly have been pointed out by Weller (18) and need no further discussion. It is important that such a desirable character as smooth skin be associated with an equally desirable one, that of disease resistance. With the exception of the investigations of Hayes et al. (17), and Gmitter (12), practically no work regarding the breeding of smooth-skinned barflies for resistance to disease has been reported. This study was undertaken with the two-fold purpose of studying the relationship existing between smooth skin and resistance to the cell disease, and the mode of inheritance of these characters. The data were also compiled as guidelines and help to plant and breeder of rockling barflies.

The pathogenes referred to above were selected for this investigation because they are the causal agents of three of the more destructive diseases of barley occurring in Western Canada. Reports on the distribution and economic importance of these diseases in Alberta are given in the reports on "Prevalence of Plant Diseases in the Dominion of Canada," for the years 1927-31 (5,6,24).

In Alberta for the five year period covered smut is designated in all years as being "common and destructive, causing important losses". The report of 1931 (5), which is fairly typical, shows 50 percent of the fields examined to be infected, a few running as high as 70 percent infection.

Loose smut of barley is reported as being of widespread distribution but the loss being much less than that caused by covered smut. It is also a significant fact that investigators have noted that smooth awned varieties are generally susceptible to the loose smut disease.

The stripe disease is reported as being less important than either of the smut diseases. However, approximately 25 percent of the fields examined in Alberta in 1930 showed infected plants, with one field exhibiting 20-30 percent infection. Work conducted at the University of Alberta shows that a number of promising new varieties are susceptible to this disease. The practice of late seeding of barley probably accounts for the small percentages of infection noted in the surveys.

The various reports referred to above were selected for

this investigation because they are the central agents of
three of the more distinctive diseases of barley occurring
in Western Canada. Reports on the distribution and economic
importance of these diseases in Alberta are given in the
reports on "Prevalence of Barley Diseases in the Province of
Canada," for the years 1914-15 (p. 4, 5, 6).

In Alberta for the five year period covered and
is designated in all years as being "common and destructive",
causing important losses". The report of 1921 (p. 10), which
is fairly typical, shows 80 percent of the fields examined
to be infected, a few running as high as 90 percent infec-
tion.

Losses amount of barley is reported as being of impor-
tance distributed but the loss being much less than that
caused by covered smut. It is also a significant loss and
generally susceptible to the loss smut disease.

The smut disease is reported as being impor-
tant than either of the other diseases. However, reports
investigations of the disease in the fields in 1914-15
showed infected plants, with one field showing 20-30 per-
cent infection. When compared at the University of Alberta
shows that a number of promising new varieties are susceptible
to this disease. The practice of late sowing of barley
probably accounts for the small percentage of infection
noted in the surveys.

Mention has already been made regarding the dearth of literature concerning the breeding of smooth awned barleys for disease resistance. In fact, it may be said that as compared to wheat and oats, little work along disease resistance lines has been reported in barley. There are a number of reasons for this.

In the first place, the relatively lower economic value of the barley crop has not stimulated the same interest in the development of disease-resistant varieties as has occurred in wheat and oats. Furthermore, the early development of control measures did much to discourage any breeding investigations. Probably the most important factor handicapping the breeding of resistant varieties is the lack of a satisfactory ^{inoculation} technique for obtaining infection. Many difficulties are encountered if the seeds are dehulled. Dehulling by hand is impracticable in large populations whereas the use of chemicals is still in the experimental stage and offers many difficulties. Floral inoculation is a very laborious process even when undertaken in the most favourable of conditions, as in the greenhouse. When carried out in the field, environmental factors render the results very uncertain. The weak straw of the barley plant aggravates the problem if the heads are to be bagged.

The presence of physiologic forms and a lack, in a great many instances, of adequate knowledge regarding *the* influence of environmental factors on infection, serve as further barriers to the obtaining of high percentages of smut in susceptible varieties.

PARENTAL MATERIAL.

The barley varieties used in the investigation under consideration were two smooth awned types, Glabron and Velvet and a rough awned type, Trebi. Reciprocal crosses were made between Trebi and each of the smooth awned varieties.

Trebi is a six-rowed rough awned variety resulting from a pure line selection made in 1907 in the cooperative breeding experiments conducted by the United States Department of Agriculture and the Minnesota Agricultural Experimental Station, at St. Paul (15). This barley has bluish-grey kernels possessing short haired rachillas. It is weak strawed but yields exceptionally well. It is very susceptible to H. sativum; moderately susceptible to U. hordei; and resistant to U. nuda and H. gramineum.

Glabron and Velvet are six-rowed smooth awned varieties developed at the Minnesota Agricultural Experiment Station (18). Glabron was developed from a back-cross between Smooth Awn (a selection from a cross between Lion and Manchuria) and Manchuria, whereas Velvet resulted from a cross between Smooth Awn and Luth.

Glabron yields well and possesses a stiff straw. It is moderately susceptible to H. gramineum, susceptible to U. nuda and resistant to U. hordei and H. sativum. The kernels of this barley have the long-haired rachillas as compared to short-haired type possessed by Trebi.

The barley varieties used in the investigation under consideration were two smooth eared types, Glabron and Velvet and a rough eared type, Trebi. Reciprocal crosses were made between Trebi and each of the smooth eared varieties.

Trebi is a six-rowed rough eared variety resulting from a pure line selection made in 1907 in the cooperative breeding experiments conducted by the United States Department of Agriculture at St. Paul (15). This barley has bluish-grey kernels possessing short haired rachilla. It is weak strawed but yields exceptionally well. It is very susceptible to H. sativum; moderately susceptible to U. hordei; and resistant to U. ruga and U. graminum.

Glabron and Velvet are six-eared smooth eared varieties developed at the Minnesota Agricultural Experiment Station (16). Glabron was developed from a back-cross between Smooth Awn (a selection from a cross between Lion and Manchuria) and Manchuria, whereas Velvet resulted from a cross between Smooth Awn and Ruth. Glabron yields well and possesses a stiff straw. It is moderately susceptible to H. sativum, susceptible to U. ruga and resistant to U. hordei and U. graminum. The kernels of this barley have the lanceolate rachilla as compared to short-haired type possessed by Trebi.

Velvet is not quite so desirable from an agronomic point of view as Glabron. It is not only lower in yield but possesses a decidedly weaker straw. It is very susceptible to H. gramineum and U. nuda, but shows resistance to H. sativum and U. hordei.

GENERAL METHODS.

The reciprocal crosses of Velvet and Trebi were studied in the F_1 and F_2 only, whereas those of Glabron and Trebi were carried into the F_3 . All generations were grown on the experimental plots of the University of Alberta. The F_2 and F_3 with the parental varieties were seeded in ten-foot rows, one foot apart. Approximately fifty seeds were sown per ten-foot row in the F_3 .

Barbing of awns was studied in the F_1 and F_2 of crosses involving Velvet and Trebi, and in the F_1 , F_2 and F_3 of the reciprocal crosses of Glabron and Trebi. All other characters reported in this paper were studied in the F_3 of crosses involving Glabron and Trebi, with the exception of length of rachilla hairs which was investigated in the F_2 of this cross.

The seeds of all F_2 plants with the exception of some 500 plants inoculated with a spore suspension of H. gramineum, were divided, when the number of seeds permitted, into three lots of approximately 50 seeds each.

Velvet is not quite as desirable from an economic point of view as Glabrous. It is not only lower in yield but possesses a decidedly weaker straw. It is very susceptible to *A. glaucospora* and *A. nivalis*, but shows resistance to *A. nivalis* and *A. glaucospora*.

The reciprocal crosses of Velvet and Thrift were studied in the F_2 and F_3 only, whereas those of Glabrous and Thrift were carried into the F_4 . All generations were grown on the experimental plots of the University of Alberta. The F_2 and F_3 with the parental varieties were seeded in ten-foot rows, one foot apart. Approximately thirty seeds were sown per ten-foot row in the F_2 .

Seeds of F_2 were sown in the F_3 and F_4 in the same manner as the parental varieties, and in the F_3 and F_4 of the reciprocal crosses of Glabrous and Thrift. All other characters reported in this paper were obtained in the F_2 of crosses involving Glabrous and Thrift, with the exception of length of rachilla hairs which was investigated in the F_3 of this cross.

The seeds of all F_2 plants which were selected for some 500 plants inoculated with a spore suspension of *A. glaucospora*, were divided, when the number of seeds was small, into approximately 50 seeds each.

These were sown in genetic, covered smut and loose smut nurseries, respectively. In the ~~ad~~^{event} of insufficient seed, the preference was given first to the genetic nursery and then to the covered smut nursery.

The seed of the F_2 plants, from which two heads had been inoculated with a spore suspension of H. gramineum, were seeded in both genetic and stripe nurseries.

INHERITANCE OF CHARACTERS.

Barbing of Awns

Literature review.

The first crosses between rough and smooth awned barleys to be recorded in the literature were made by Harlan in 1912 (13). He concluded from a study of these that the rough awned condition was dominant and a single factor was involved.

Extensive studies on the smooth awn condition in barley were made by Vavilov (39). He was able to obtain smooth awned types from the F_2 and F_3 of a cross between two rough awned varieties. Studies of numerous crosses between parents of varying degrees of smoothness resulted in complicated ratios. He concluded from his investigations that "five to six factors were necessary to explain the

... in genetic, covered and ...
nursery, respectively. In the event of ...
the preference was given first to the genetic nursery and
then to the covered seed nursery.
The seed of the F_2 plants, from which two heads had
been inoculated with a spore suspension of *M. tritici*, were
sown in both genetic and covered nurseries.

Results of the ...

The first crosses between rough and smooth ...
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Extensive studies on the smooth and rough ...
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smooth and rough types from the F_2 and F_3 of a cross ...
two rough and smooth varieties. Studies of numerous ...
these parents of varying degrees of smoothness ...
...
...

form, character, density and arrangement of the teeth on the awn on the races studied".

Hayes et.al.(17) working at the Minnesota Experimental Station with the varieties Lion (smooth awned) and Manchuria (rough awned) report that all F_1 plants had rough awns, while the F_2 generation segregated in an approximate ratio of 3 rough awned plants to one smooth. To improve upon the method of determining the degree of smoothness an index system was devised. This was accomplished by dividing the total length of the awn by the portion barbed. The larger the index the smoother^{was} the awn. All smooth awned F_2 plants bred true in the F_3 generation for the smooth awn condition. However, it was noticed that some bred true for only low indices, some only for high indices, whereas others produced plants of both low and high indices. A number of the F_3 lines classed as rough awned in the F_2 bred true, whereas others broke up into rough and smooth awned types reflecting the F_2 generation. The authors believe that in addition to one main factor difference between rough and smooth awn, modifying factors brought in by the rough awned parent are required to explain the different degrees of smoothness.

Griffiee (12) was able to divide the F_2 ^{of a cross Lion x Swan Lake} into three phenotypes based on an arbitrary index. The types, rough, intermediate-smooth and smooth were obtained in a 12:3:1 ratio, thus indicating a 2-factor difference. The results were explained on the bases of epistasis.

imental station with the varieties (non-rough) and
Mammoth (rough) report that all F_1 plants had rough
awn, while the F_2 generation segregated in an approximate
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 F_2 lines assessed as rough awned in the F_3 bred true, whereas
as others broke up into rough and smooth awned types reflecting
the F_2 generation. The authors believe that in addition
to one main factor difference between rough and smooth awn
modifying factors brought in by the rough awned parent are
required to explain the different degrees of awniness.
Griffith (19) was able to divide the F_2 into rough
and smooth based on an arbitrary index. The rough
and smooth were obtained in a 3:1
ratio. This indicates a 2-factor difference. The results

The factor R when present produces rough awns; the other factor S is hypostatic to R and in the absence of R produces intermediate-smooth condition. The double recessive rrss expresses the smooth awn type. Griffée also ^{noticed} ~~experienced~~ much variation in the degree of smoothness amongst smooth awned lines and for this reason supports the view of Hayes et.al., (17) that certain minor factors are operative.

Sigfusson (31) obtained results somewhat similar to those of Griffée. He classified the F_2 into four phenotypes as follows: (a) rough, (b) intermediate-rough, (c) intermediate-smooth and (d) smooth. The first two classes were totally barbed but the barbs of the second group were decidedly less scabrous than those of the first. The third group was smooth at the base only, whereas the fourth was smooth to a few centimetres of the tip. The distribution in the F_2 gave a very close fit to a 9:3:3:1. Sigfusson explained his results on a 2-factor basis as follows:

"the factor R either single or in duplicate and in the absence of S produces the intermediate-rough condition and similarly the factor S in the absence of R produces the intermediate-smooth condition. The factor R is the main factor and produces a greater effect than S but both are necessary either singly or in duplicate to produce the fully rough class. The smooth class is the double recessive and has the genetic constitution rrss."

The factor R when present produces roughness; in the absence of R the factor S is hypothesized to be in the absence of R produces roughness. The double recessive trait expresses the smooth skin type. Critics also have pointed out variation in the degree of smoothness amongst smooth-skinned lines and for this reason supports the view of Hayes et al., (1961) that certain minor factors are operative.

Wasson (1961) obtained results somewhat similar to those of Griffice. He classified the F_2 into four phenotypic types as follows: (a) rough, (b) intermediate-rough, (c) intermediate-smooth and (d) smooth. The first two classes were totally banded but the bands of the second group were decidedly less accentuated than those of the first. The third group was smooth at the base only, whereas the fourth was smooth to a few centimetres of the tip. The distribution in the F_2 gave a very close fit to a 9:3:3:1. Griffice explained his results on a 3-factor basis as follows:

"the factor R either alone or in conjunction with the factor S produces the intermediate-rough condition and similarly the factor S in the absence of R produces the intermediate-smooth condition. The factor R is the main factor and produces a greater effect than S but both are necessary to obtain the rough condition. The factor S produces the smooth condition in the absence of R. The double recessive trait is the smooth skin type."

David (7) arrived at quite different conclusions ~~than~~ ^{from} any of his predecessors. His contribution to the question is of special interest since he worked with similar crosses to those reported in this paper, viz., Glabron x Trebi and Velvet x Trebi. The F_2 segregated into what appeared to be a normal 3:1. However, the F_3 behavior could not be explained on the basis of a 3:1 hypothesis for about $2/3$ of the smooth awned F_2 plants gave rise to F_3 progeny segregating ^{in the ratio of} 3 smooth awned to 1 rough awned. As this suggested the presence of an inhibitor, David compared the F_2 data with the theoretical 13:3 ratio. The fit was found to be good. He assumed there was present a dominant factor ^{A for} ~~I~~ inhibiting smooth awn. The smooth awned parent had the constitution $AAii$, the rough awned parent, $aaII$.

Robertson, Deming and Koonce (30) as a result of F_2 study of ^aCoast x Lion cross confirmed the findings of Griffiee (12) in that the segregation of the F_2 approached a 12:3:1. The index method of determining smoothness was utilized (17).

Recently Wexelson (42) found a single factor difference between rough and smooth awns. The smooth awned segregates are reported as being as smooth as the smooth awned parent.

... to those reported in this paper, viz., 10:1.

Tried and Valves in Tread. The T_2 concentration ratio was

appeared to be a normal 3:1. However, the T_2 inhibitor could

not be explained on the basis of a 3:1 hypothesis for which

of the smooth owned T_2 plants were also to T_2 property

segregating 3 smooth owned to 1 rough owned. As this

suggested the presence of an inhibitor, Davis compared the

T_2 data with the theoretical 15:3 ratio. The fit was found

to be good. He assumed there was present a dominant factor

1 inhibiting smooth own. The smooth owned parent had 15

smooth owned parent, 15:1.

Robertson, Gemma and Thomas (30) as a result of

T_2 study of Coast x Lion cross confirmed the findings of

Griffie (12) in that the segregation of the T_2 gene was

a 15:3:1. The index method of determining smoothness was

used.

Recently Anderson (41) found a similar factor

difference between rough and smooth own. The smooth owned

parent was reported as being an ancestor of the smooth

Methods and experimental results.

The degree of barbing of the awns was determined by simply passing the awns between the fingers, ~~aided~~ *This* ~~when necessary~~ *was supplemented* by the use of a hand lens. This simple and rapid method was adopted rather than the more complex index system, because of the large F_2 population to be studied and because it was thought that an arbitrary index might be concealing the true phenotypic classes.

An examination of a large number of plants of the smooth awn^{ed} parent showed a considerable variation in the degree of barbing of the awns. This varied from a few barbs at the extreme tips of the awns to barbs extending one-quarter of the length of the awns.

The F_1 of all the crosses studied were rough awned. It was comparatively simple to separate the F_2 plants into two main groups. Those with completely rough awns and those with awns exhibiting some degree of smoothness. Greater difficulty was experienced in establishing classes within these two groups. After considerable study it was decided that the F_2 material fell into the following five classes:

1. Rough awned
2. Intermediate-rough awned
3. Smooth base
4. Intermediate-smooth awned
5. Smooth awned.

on necessity by the use of a hand lens. This simple and rapid method was adopted rather than the more complex index system because of the large T_2 population to be studied and because it was thought that an arbitrary index might be concealing the true phenotypic classes.

An examination of a large number of plants of the smooth awn parent showed a considerable variation in the degree of bending of the awns. This varied from a few barbs at the extreme tips of the awns to barbs extending one-quarter of the length of the awns.

The F_2 of all the crosses studied were roughly awned. It was comparatively simple to separate the F_2 plants into two main groups. Those with completely round awns and those with awns exhibiting some degree of awning. Greater difficulty was experienced in separating classes within these two groups. After considerable study it was decided that the F_2 material fell into the following

1. Round awned
2. Intermediate-round awned
3. Smooth awned
4. Intermediate-smooth awned

The first two classes have fully barbed awns; but the barbs of the second class are much less scabrous than those of the first. The awns of class 3 have barbs extending along 50-75 percent of their length, whereas, in class 4 the barbs seldom extend over 50 percent of the length of the awn and are not as scabrous. Class 5 reflects the smooth awn parental type. An average awn of each of the five classes is illustrated diagrammatically in Figure I. Considerable variation was observed within these classes and for this reason it was thought that environmental factors might be responsible for the intermediate-rough and smooth base classes. Accordingly, the segregation of F_2 plants for barbing of awn in the crosses studied have been based upon three phenotypes; rough, intermediate-smooth and smooth; the two rough classes and the two intermediate-smooth classes having been grouped.

This grouping suggested a 12:3:1 ratio of rough : intermediate-smooth : smooth awned plants. The actual segregations as compared to the theoretical 12:3:1 are given in Tables I and II. The fit of the actual to the theoretical in the crosses involving Trebi and Glabron, (Table I) is fairly good in some cases, but owing to the tendency to place a number of intermediate-smooth plants in the smooth awned class, the total population shows a poor fit to the theoretical.

ly peaked away; but the bars
of these classes than those of the

the

75 percent of their length, whereas, in class 4 the length

extends over 50 percent of the length of the arm and

are not as numerous. Class 5 reflects the smooth arm

parental type. An average arm of each of the five classes

is illustrated diagrammatically in Figure 1. Considerable

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reason it was thought that environmental factors might be

responsible for the intermediate-rough and smooth arm differ-

es. Accordingly, the segregation of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000

of arm in the crosses studied have been based upon these

phenotypes; rough, intermediate-smooth and smooth; the

two rough classes and the two intermediate-smooth classes

having been grouped.

This grouping suggested a 16:8:1 ratio of arms:

intermediate-smooth : smooth armed plants. The actual

segregations as compared to the theoretical 16:8:1 are

given in Tables I and II. The fit of the actual to the

theoretical in the crosses involving Trebb and Johnson,

(Table I) is Table III. The fit is also good, but owing to

tendency to place a number of intermediate-smooth plants

in the smooth armed class, the total population cannot

be fit to the theoretical.

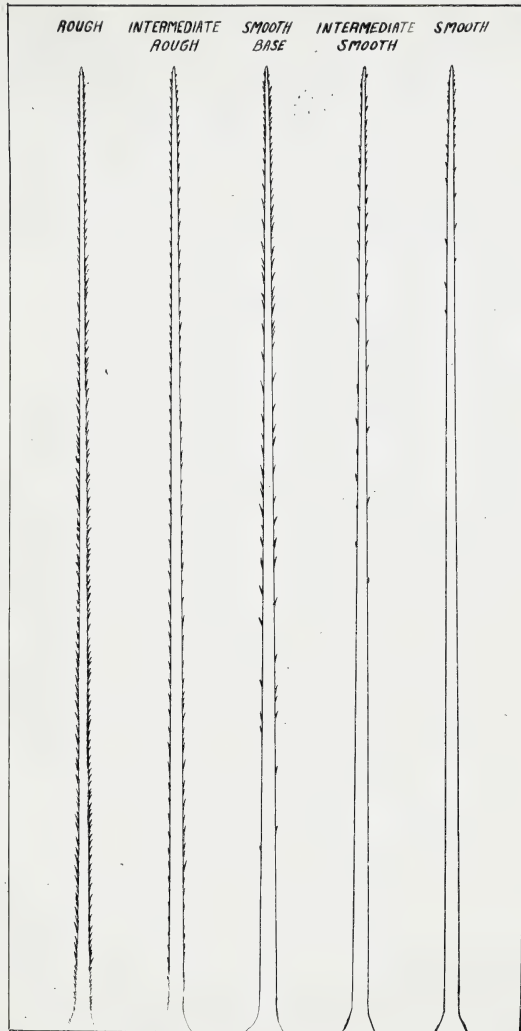


FIGURE I.

Diagrammatic length-wise section of average awn of each of five awn classes: Rough, intermediate-rough, smooth base, intermediate-smooth and smooth; used in classification of F_2 of reciprocal crosses Glabron and Trebi and Velvet and Trebi.

TABLE I.

Numbers of rough, intermediate-smooth and smooth awned plants in the F₂ generation of reciprocal crosses between Glabron and Trebi, as compared to the theoretical 12:3:1 ratio.

Cross	number.	Actual			Theoretical			X ²	P
		Rough	Inter- medi- ate smooth	Smooth	Rough	Inter- medi- ate smooth	Smooth		
Glabron x Trebi	6	111	21	7	104.28	26.07	8.69	1.75	0.43
	11	133	21	18	129.00	32.25	10.75	9.64	0.01
	12	170	32	16	163.50	40.88	13.63	2.60	0.28
	13	121	29	18	126.00	31.50	10.50	5.71	0.06
Trebi x Glabron	19	79	24	13	87.00	21.75	7.25	5.64	0.06
	20	158	33	14	153.75	38.44	12.81	1.00	0.61
	21	95	20	5	90.00	22.50	7.50	0.84	>0.61
	23	83	13	8	78.00	19.50	6.50	2.83	0.25
	45	136	22	10	126.00	31.50	10.50	3.68	0.16
Total		1086	215	109	1057.56	264.39	88.13	14.93	0.001

The reciprocal crosses of Trebi and Velvet together with their total show, on the other hand, good fits to the theoretical (Table II). This may be explained by the fact that as this cross was studied last, a greater familiarity with the different phenotypes was experienced.

TABLE I

Analysis of results, interrelationships and general trends in the 19 generation of reciprocal crosses between *Glabron* and *Trobl*, as compared to the *Glabron* x *Trobl* cross.

Cross		1967		1968		1969	
Cross		1967		1968		1969	
Glabron x Trobl		6	111	21	7	104.88	28.07
Trobl x Glabron		10	79	24	12	87.00	21.78
Trobl x Trobl		20	127	32	14	103.75	28.44
Glabron x Glabron		21	95	20	5	90.00	22.50
Trobl x Trobl		25	85	15	8	78.00	15.80
Glabron x Trobl		45	138	28	10	122.00	31.40

The reciprocal crosses of *Trobl* and *Glabron* families with their total show on the other hand, good fits to the theoretical (Table II). This may be explained by the fact that as this cross was studied last, a greater reliability

TABLE II.

Numbers of rough, intermediate-smooth and smooth awned plants in F_2 generation of reciprocal crosses between Velvet and Trebi, as compared to the theoretical 12:3:1 ratio.

Cross	Number.	Actual			Theoretical			χ^2	P
		Rough	Inter-Smooth	med.-Smooth	Rough	Inter-Smooth	med.-Smooth		
Trebi x Velvet	116	59	15	8	61.50	15.38	5.13	1.72	0.44
	123	160	30	12	151.50	37.88	12.63	2.15	0.35
	124	155	37	16	156.00	39.00	13.00	less than 1	>0.61
	133	186	50	19	191.38	47.82	15.94	1.73	0.43
Velvet x Trebi	137	183	45	16	183.00	45.75	15.25	less than 1	>0.61
	146	123	22	6	113.16	28.29	9.44	3.51	0.18
	148	188	41	14	182.28	45.57	15.19	less than 1	>0.61
	151	114	23	8	108.72	27.18	9.06	1.02	0.60
Total		1168	263	99	1147.56	286.89	95.63	2.47	0.30

The F_2 data just presented would seem to indicate a two factor difference for barbing of awn. It can be explained on the basis of epistasis; R is the main factor for barbing of awn; S is hypostatic to R and in the absence of R produces the intermediate-smooth condition, while the double recessive produces the smooth awn type. On the basis of

TABLE 12

Numbers of rough, intermediate-smooth and smooth stages in F₂ generation of reciprocal crosses between Velvet and Smooth, as compared to the F₁ generation and P₁ parents.

Class	Number	Smooth	Intermediate	Rough
Velvet x Velvet	118	59	15	8
122	180	30	12	181.50
124	152	37	18	150.00
126	136	50	19	191.56
Velvet x Smooth	127	126	31	100.76
130	121	33	3	122.78
132	188	41	14	182.28
134	114	38	10	124.75
Total	1183	383	92	1114.56
				234.00
				2.40

The F₂ data just presented would seem to indicate a two factor difference for banding of awn. It can be explained on the basis of epistasis; R is the main factor for banding of awn; S is hypostatic to R and in the absence of R produces the smooth awn type. On the basis of

this hypothesis the F_2 plants, when tested in the F_3 , should breed as follows:

Rough-awned plants:

- 4 Breeding true for rough
- 4 Segregating in the ratio 12:3:1 for rough : intermediate-smooth : smooth
- 2 Segregating 3 rough : 1 intermediate-smooth
- 2 Segregating 3 rough : 1 smooth.

Intermediate-smooth awned plants:

- 1 breeding true for intermediate-smooth
- 2 segregating 3 intermediate-smooth : 1 smooth

Smooth awned plants:

Breeding true for smooth awn.

Three crosses involving Trebi and Glabron were given further study in the F_3 .

The behavior of F_3 lines from plants classified as rough awned in the F_2 is given by the data in Table III.

TABLE III.

The behavior of F_3 lines from plants classified as rough awned in F_2 , compared with the theoretical ratio 2:2:1:1.

Cross Number	Non-seg		Seg.12:3:1		Seg.3 rough: 1 int.-smooth		Seg.3 rough: 1 smooth		X ²	P	
	Act.	Theor.	Act.	Theor.	Act.	Theor.	Act.	Theor.			
Glabron x Trebi	12	63	47.67	29	47.67	32	23.83	19	23.83	15.960	0.001
Trebi x Glabron	21	24	26.67	25	26.67	17	13.33	14	13.33	1.42	0.71
Trebi x Glabron	45	39	36.00	33	36.00	22	18.00	14	18.00	2.28	0.52
Total of Crosses 21 & 45		63	62.67	58	62.67	39	31.33	28	31.33	2.58	0.47

The fits are remarkably close to the theoretical in crosses 21 and 45, but a wide deviation occurs in the case of cross 12. It will be seen that the homozygous rough awned lines are too numerous, whereas, those segregating in the ratio of 12:3:1 are too few in number. This poor fit is very difficult to explain as it would seem very unlikely that lines segregating for any degree of smoothness would be placed in the homozygous rough awned class. An examination of the data in Tables V, VI and VII shows that the ratios of segregating plants within the F_3 lines resulting from rough awned F_2 plants are quite normal.

The behavior of F_3 lines from plants classified as intermediate-smooth in the F_2 is supplied by the data given in Table IV.

TABLE IV.

The behavior of F_2 lines from plants classified as intermediate smooth awned, in F_2 , compared with the theoretical ratio 1 : 2.

Cross Number		Non-seg.		Seg. 3 int.-smooth : 1 smooth	
		Act.	Theor.	Act.	Theor.
Glabron x Trebi	12	19	13.66	22	27.32
Trebi x Glabron	21	7	7.00	14	14.00
<i>Trebi</i> x <i>Glabron</i>	45	13	9.00	14	18.00
Total		39	29.66	50	59.32

A very close fit to the expected is obtained in cross 21. Certain deviations occur in crosses 12 and 45 that can possibly be explained by the fact that when only small numbers of smooth awned plants occurred in segregating lines they were overlooked and classified as intermediate-smooth. Further evidence of the difficulties encountered in distinguishing these two types is supplied by the data in Table VIII, where it will be seen that the F_3 segregating lines derived from intermediate-smooth awned F_2 plants contain too many intermediate-smooth awned types at the expense of the smooth awned. This accounts for the poor fits to the theoretical obtained in these (~~in these~~) instances.

The behavior of T_2 lines from plants class-
ified as intermediate-smooth varied in
 T_2 , compared with the theoretical
ratio 1 : 2.

Total	48	16	29.88	50	52.32
Control	48	16	3.00	14	18.00
Tribl x Clabron	21	7	7.00	14	14.00
Tribl	18	12	18.80	38	37.32

A very close fit to the expected is obtained in cross 21.
Certain deviations occur in crosses 18 and 48 that can pos-
sibly be explained by the fact that when only small numbers
of smooth seeded plants occurred in segregating lines they
were overlooked and classified as intermediate-smooth. Fur-
ther evidence of the difficulties encountered in distinguishing
these two types is supplied by the data in Table VIII,
where it will be seen that the T_2 segregating lines derived
from intermediate-smooth seeded T_2 plants contain too many
intermediate-smooth types at the expense of the smooth
seeded. This accounts for the poor fits to the theoretical
obtained in these instances.

TABLE V.

Summary of the ratios of rough : intermediate-smooth : smooth awned plants in F_3 segregating lines, compared with the theoretical 12:3:1.

Cross Number			Rough	Inter.- Smooth	Smooth	χ^2	P
Glabron x Trebi	12	Act.	879	226	85	1.76	0.47
		Theor.	892.50	223.13	74.38		
Trebi x Glabron	21	Act.	800	182	70	1.61	0.46
		Theor.	789.00	197.25	67.25		
Trebi x Glabron	45	Act.	1014	258	89	0.27	>0.61
		Theor.	1020.75	255.19	85.06		

TABLE VI.

Summary of the ratios of rough : intermediate-smooth awned plants in F_3 segregating lines, compared with the theoretical 3:1.

Cross Number			Rough	Inter.- Smooth	Dev. P.E.	Odds
Glabron x Trebi	12	Act.	969	268	4.02	142.26:1
		Theor.	927.75	309.25		
Trebi x Glabron	21	Act.	551	165	1.77	3.45:1
		Theor.	537.00	179.00		
Trebi x Glabron	45	Act.	674	200	2.14	5.38:1
		Theor.	655.50	218.50		

Summary of the ratios of rough : intermediate-smooth
 owned plants in W. separating lines,
 compared with the theoretical 2:1.

Plant Number	Rough	Inter- Smooth	Smooth	Ratio
Plant 1 Treat 1	12	Act.	870	85
Plant 2 Treat 2	21	Act.	800	70
Plant 3 Treat 3	45	Act.	1014	80
		Theor.	1020.75	85.00

TABLE VI.

Summary of the ratios of rough : intermediate-smooth
 owned plants in W. separating lines, compar-
 ed with the theoretical 2:1.

Plant Number	Rough	Inter- Smooth	Smooth	Ratio
Plant 1 Treat 1	12	Act.	900	85
Plant 2 Treat 2	21	Act.	851	75
		Theor.	857.00	75.00
Plant 3 Treat 3	45	Act.	874	80
		Theor.	886.50	81.50

TABLE VII.

Summary of the ratios of rough : smooth awned plants
in F_3 segregating lines, compared with the
theoretical 3:1.

Cross Number			Rough	Smooth	$\frac{\text{Dev.}}{\text{P.E.}}$	Odds
Glabron x Treb1	12	Act.	536	192	1.29	1.63:1
		Theor.	546.00	182.00		
Treb1 x Glabron	21	Act.	445.00	146.00	less than 1	<1:1
		Theor.	443.25	147.75		
Treb1 x Glabron	45	Act.	367	126	less than 1	<1:1
		Theor.	369.75	123.25		

TABLE VIII.

Summary of the ratios of intermediate-smooth to
smooth awned plants in F_3 segregating lines
compared with the theoretical 3:1.

Cross Number			Inter.- Smooth	Smooth	$\frac{\text{Dev.}}{\text{P.E.}}$	Odds
Glabron x Treb1	12	Act.	685	171		
		Theor.	642.00	214.00	5.04	1350.35 : 1
Treb1 x Glabron	21	Act.	404	116		
		Theor.	390.00	130.00	2.10	5.38 : 1
Treb1 x Glabron	45	Act.	447.00	102		
		Theor.	411.75	137.25	5.15	1350.35 : 1

It will be recalled that the F_2 material was originally classified into five classes. The data in Table IX show the distribution of the plants of the five F_2 groups on the basis of the breeding behavior in the F_3 . Before discussing the data contained in this Table, it would be well to bring out the interesting observation that all the homozygous intermediate-smooth F_3 lines were composed of plants possessing awns having the characteristic smooth-base type of barbing, whereas, the segregating lines contained plants with both types of intermediate-smooth awns. This observation is supported by the data contained in Table IX. With reference to crosses 21 and 45 (cross 12 was not classified for the smooth-base type) it will be seen that the majority of the F_2 plants classified as smooth-base bred true, whereas, those F_2 plants classified as intermediate-smooth awned segregated. The data submitted, indicate that it is possible to separate the two genotypes $rrSS$ and $rrSs$ on the basis of their respective phenotypes. The factor S in homozygous condition causes a more pronounced type of barbing than it does in the heterozygous condition.

The data in Table IX also show the non-validity of the intermediate- rough class, since plants classified as such in F_2 behaved either as rough or as smooth base types. The F_3 behavior justifies the grouping adopted in the F_2 .

It will be seen that the F_2 material was obtained
with classified into two groups. The data in Table IX
show the classification of the plants of the five F_2 groups
as to the type of banding. In the F_2 groups
discussing the data contained in this Table, it would be
well to bring out the interesting observations that all the
homozygous intermediate-smooth F_2 lines were composed of
plants possessing a smooth banding, whereas the heterozygous lines con-
tained plants with both types of intermediate-smooth ams.
This observation is supported by the data contained in Table
IX. With reference to crosses 81 and 48 (cross 18 was not
classified for the smooth-band type) it will be seen that
the majority of the F_2 plants classified as smooth-band
bred true, whereas those F_2 plants classified as intermediate-
smooth banded segregator. The data submitted indicate that
it is possible to separate the two genotypes into two
on the basis of their respective phenotypes. The factor S
in homozygous condition causes a more pronounced type of
banding than it does in the heterozygous condition.
The data in Table IX also show the same result.
The intermediate-smooth banding, which is observed
in F_2 observed either as rough or as smooth band type.
The behavior justifies the grouping shown in Table IX.

TABLE IX.

Distribution of the plants of the five original F_2 classes according to F_3 behavior.

F_2 classes F_3 behavior	Glabron x Trebi, Cross 12.			Trebi x Glabron, Cross 21			Trebi x Glabron, Cross 45		
	Rough Int.- base	Smooth Int.- base	Smooth Int.- oth	Rough Int.- base	Smooth Int.- oth	Rough Int.- oth	Rough Int.- base	Smooth Int.- oth	Smooth Int.- oth
Rough	139	1		76		98			1
Int.-Rough	1	5		4		8	3		
Smooth base	1				6	2	7	1	
Int.-Smooth		13	15		1	10	3	8	
Smooth			7		2	3		4	6
Total	141	19	22	80	7	14	3	108	13
			8					14	6

A further study of the data in this table reveals the fact that a number of plants classified as smooth awned in the F_2 behaved as intermediate-smooth awned in the F_3 . The actual ratios of the F_2 plants tested in the F_3 , together with the corrected ratios, are given in Table X.

TABLE X.

Comparison of uncorrected and corrected F_2 ratios with the theoretical 12:3:1.

Cross Number			Rough	Inter.- Smooth	Smooth	χ^2	P
Glabron x Trebi	12	Un- correct.	146	29	15	2.14	0.35
		Correct.	141	41	8	2.10	0.35
		Theor.	142.50	35.63	11.88		
Trebi x Glabron	21	Un- correct.	80	19	5	0.09	very high
		Correct.	80	21	3	2.05	0.36
		Theor.	78.00	19.50	6.50		
Trebi x Glabron	45	Un- correct.	109	22	10	1.90	0.39
		Correct.	108	27	6	1.39	0.51
		Theor.	105.75	26.44	8.81		
Total		Un- correct.	335	70	30	2.04	0.36
		Correct.	329	89	17	4.73	0.10
		Theor.	326.25	81.56	27.19		

A further group of the data in this table reveals the fact that a number of the plants tested in the T_2 group of interest in the late-smooth series owned in the T_2 group. Actual values for the T_2 plants tested in the T_2 group, with the corrected values, are given in Table 1.

TABLE 1

Comparison of uncorrected and corrected T_2 values with the corrected T_1 values.

Plant Number	Uncorrected T_2	Corrected T_2	Corrected T_1	Plant Number
1	1.00	1.00	1.00	11
2	1.00	1.00	1.00	12
3	1.00	1.00	1.00	13
4	1.00	1.00	1.00	14
5	1.00	1.00	1.00	15
6	1.00	1.00	1.00	16
7	1.00	1.00	1.00	17
8	1.00	1.00	1.00	18
9	1.00	1.00	1.00	19
10	1.00	1.00	1.00	20
21	1.00	1.00	1.00	31
22	1.00	1.00	1.00	32
23	1.00	1.00	1.00	33
24	1.00	1.00	1.00	34
25	1.00	1.00	1.00	35
26	1.00	1.00	1.00	36
27	1.00	1.00	1.00	37
28	1.00	1.00	1.00	38
29	1.00	1.00	1.00	39
30	1.00	1.00	1.00	40

The individual crosses of the corrected F_2 data show satisfactory fits to the theoretical but as the number of smooth awned plants are low in all three cases the fit of the total is not so satisfactory.

The F_3 data presented, support rather well the original hypothesis that two factors explained on the basis of epistasis are involved in barbing of awn. The results are, therefore, in agreement with those reported by Griffee (12) and Robertson, Deming and Koonce (30).

It is interesting to note that the results of this study are not in agreement with those of David (7), who, as it has been stated, previously worked with the same cross as ^{is discussed} ~~used~~ in this paper. He reported that two-thirds of the progeny from smooth awned plants segregated in ratios approximating 3 smooth : 1 rough. No such inverse ratio occurred in the present work. It is possible that these two investigations have been carried out with different strains of barley known as Trebi. David describes Trebi as being "Six-rowed, white, high yielding, rough-awned variety". It is not clear as to what sense he is using the word "white". If he is referring to the aleurone color, then he is definitely working with a different strain of Trebi than was employed in the present study. The aleurone color of the kernels of the Trebi parent used in this investigation was definitely bluish-grey. *This description of the kernel color of Trebi is in accord with the description given by Harlan et al (43)*

The individual crosses of the corrected F_2 data show satisfactory fits to the theoretical but as the number of smooth-seeded plants are low in all three cases the fit of the total is not so satisfactory.

The F_2 data presented support rather well the original hypothesis that two factors explained on the basis of epistasis are involved in bending of awn. The results are, therefore, in agreement with those reported by Griffies (18) and Robertson, Deming and Noonce (20).

It is interesting to note that the results of this study are not in agreement with those of David (7), who, as it has been stated, previously worked with the same cross as used in this paper. He reported that two-thirds of the progeny from smooth-seeded plants segregated in ratios approximating 3 smooth : 1 rough. No such inverse ratio occurred in the present work. It is possible that these two investigations have been carried out with different strains of barley known as Trebi. David has been "Six-rowed, white, high awnless, rough-seeded variety". It is not clear as to what variety he is using the word "white". If he is referring to the aleurone color, then he is definitely working with a different strain of Trebi than was employed in the present study. The aleurone color of the kernels of the Trebi parent used in this investigation was definitely bluish-grey.

LENGTH OF RACHILLA HAIRS.

Literature review.

The short-haired rachilla is always covered with short, fine, woolly-like hairs, while the long-haired rachilla may be covered with either long, bristly, or long fine, hairs. Several investigators including Hor (20), Sigfusson (31), and Robertson (29) have reported a single pair of factors to be responsible for this character.

Method and experimental results.

In the present study by combining in one class all those plants having long-haired rachilla, regardless of type, a very excellent fit to a 3:1 ratio is obtained (Table XI).

TABLE XI.

Distribution of plants for rachilla hairs in the F_2 of reciprocal cross of Glabron x Trebi.

	long-haired rachilla	Short-haired rachilla	χ^2	Odds
Act.	796	287	1.7	2.98 : 1
Theor.	812.25	270.75		

Author: William Miller

These data indicate a simple monohybrid inheritance with the long-haired condition dominant.

A Linkage Study.

Literature review.

It has been shown by a number of investigators that a linkage exists between the factor pair concerned in length of rachilla hairs and the main factor pair concerned in the barbing of awn. Sigfusson (31) and Robertson , et.al. (30), working with the repulsion phase report 30.8 and 34.63 ± 1.76 percent crossing over, respectively. Hor (20) obtained 28.70 ± 3.43 percent crossing over in the repulsion phase and 34.54 ± 2.89 in the coupling phase. (Only one factor was found to be responsible for rough awn in the material used by Hor.)

Methods and experimental results.

The data in Table XII show the F_2 segregation of long versus short-haired rachilla and rough versus smooth awn. A cursory examination of the data reveals the short-haired rachilla class to contain too many rough awned plants and not sufficient intermediate-smooth and smooth awned plants. The reverse is true in the case of the long-haired rachilla class. The data indicate a linkage between one of the factor pairs responsible for rough awn and the factor pair for length of rachilla hairs. Since rough awn went into the cross with short-haired rachilla and smooth awn with long-haired rachilla, the linkage is in the form of repulsion.

A Linkage Study.

Linkage study

It has been shown by a number of investigators that a linkage exists between the factor pairs concerned in length of rachilla hairs and the main factor pairs concerned in the bending of awn. Sigmanson (51) and Robertson, et al. (52), working with the recombination phase report 30.3 and 34.6-1.75 percent crossing over, respectively. Hor (53) obtained 38.70-1.48 percent crossing over in the recombination phase and 17.7-1.75 in the non-recombination phase. It is therefore to be responsible for rough awn in the material used by Hor.

Linkage and correlation

The data in Table III show the χ^2 recombination of long-verana short-haired rachilla and rough versus smooth awn. A cursory examination of the data reveals the short-haired rachilla class to contain too many rough awned plants and not sufficient intermediate-smooth and smooth awned plants. The reverse is true in the case of the long-haired rachilla class. The data indicate a linkage between one of the factor pairs responsible for rough awn and the factor pair for length of rachilla hairs. Since rough awn was the cross with short-haired rachilla and smooth awn with long-haired rachilla, the linkage is in the form of recombination.

TABLE XII.

Distribution of F₂ plants for length of rachilla hairs and barbing² of awns, in reciprocal crosses Glabron x Trebi.

Long-haired rachilla			Short-haired rachilla			Obs.
Rough	Inter.- Smooth	Smooth	Rough	Inter.- Smooth	Smooth	
538	189	69	251	21	15	
597	149.25	49.75	215.77	53.94	17.98	Calculated on basis of 2 groups of 3 class- es each
X = 24.14			X = 26.36			

(X = 49.33 when the intermediate-smooth and smooth awned classes are grouped, that is, calculated ratio based on a 9:3:3:1.)

If S, the factor for intermediate-smooth awn, is linked with the factor for short rachilla hairs, l, then the short-haired intermediate-smooth awned class should be in excess of the theoretical. However, data in Table XII show that this class, on the contrary, has too few individuals; thus indicating that the factor for short-haired rachilla must be linked with R, the factor responsible for rough awn. Furthermore, it can be seen that ratio of intermediate-smooth; smooth awn plants within the long - and short-haired rachilla classes respectively, is fairly close to the theoretical 3:1. This is additional evidence that the factor pair Ss is independent of the factor pair Ll for rachilla hair length. On this basis the intermediate-smooth awned and smooth awned classes may be grouped in

the calculation of linkage between R and l. Using the (3:1) (3:1)ratio of Immer's Tables (21), a crossover percentage of 33.4 ± 1.7 was obtained. When the observed data were compared to the theoretical on the basis of 33.4 crossing-over a fair fit, indicated by a P value of 0.18 ,was obtained (Table XIII).

TABLE XIII.

Comparison of the observed distribution of F_2 plants for length of rachilla hairs and barbing of awn, with the calculated, on the basis of 33.4% crossing over.

<u>Long-haired rachilla</u>		<u>Short-haired rachilla</u>		
<u>Rough</u>	<u>Int.-Smooth and Smooth</u>	<u>Rough</u>	<u>Int.-Smooth and Smooth</u>	
538	258	251	36	Obs.
571.72	240.52	240.53	30.20	Calc.on basis of 33.4% cross- ing over.
$\chi^2 = 4.93$		$P = 0.18$		

It may, therefore, be concluded that a linkage exists between the main factor for barbing of awn and the factor concerned in rachilla hair length with a crossingover percentage of 33.4 ± 1.7 . These results are in close agreement with those of Sigfusson (31), Hor (20) and Robertson et.al. (30).

The relationship between the observed and calculated values of λ is shown in Figure 1.

Figure 1 shows that the observed values of λ are in good agreement with the calculated values.

The observed values of λ are in good agreement with the calculated values.

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The observed values of λ are in good agreement with the calculated values.

DISCUSSION

Comparison of the observed and calculated values of λ shows that the observed values are in good agreement with the calculated values. This indicates that the theoretical model used in the calculations is a good approximation of the actual situation.

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Earliness of Heading.

Literature review.

Harlan and Martini (16) in a study of earliness in F_1 barley hybrids found that the hybrids headed quite uniformly as compared to their respective parents. The average awn-emergence date tended to be intermediate between the respective parents. The earliness of many hybrid combinations of late varieties indicated that they contained many factors for earliness.

As a result of studying the F_3 lines of a cross between Guy Mayle x Canadian Thorpe Neatby (27) concluded that growth period was governed by three main factors. He arrived at his conclusions by estimating the number of lines containing plants of winter habit and by comparing the standard deviations of the individual lines with the average of that of the parents. When these three factors are in a homozygous recessive condition winter habit results. Canadian Thorpe was thought to carry 2 factors and Guy Mayle one.

Griffiee (12) found that earliness was governed by a single factor difference with early heading dominant. A distribution table for date of heading of F_3 lines showed the lines to be of three kinds, viz., early, segregating, and late. These three types appeared in approximately 1:2:1 ratio.

Litterature review.

Harlan and Wierling (16) in a study of earliness

in F_2 barley hybrids found that the hybrids headed earlier uniformly as compared to their respective parents. The average own-experience data tended to be intermediate between the respective parents. The earliness of many hybrids could be explained by the fact that the parents were not homozygous for earliness.

As a result of studying the F_2 lines of a cross between Guy Heale x Canadian Thorpe Neely (27) concluded that growth period was governed by three main factors. He arrived at his conclusions by estimating the number of lines containing plants of winter habit and by comparing the standard deviations of the individual lines with the average of that of the parents. When these three factors are in a homozygous recessive condition winter habit results. Canadian Thorpe was thought to carry 2 factors and Guy

Neely one.

Carlson (12) found that earliness was governed

by a single factor. A distribution table for rate of heading of F_2 lines showed the lines to be of three kinds, viz., early, intermediate, and late. These three types appeared in approximately

1:2:1 ratio.

David (7) studied the inheritance of earliness in the cross that is under discussion in this paper. The F_1 was earlier than either parent. When the F_2 plants were graphed on the basis of the number of days from planting to flowering, a ratio of nine early to seven late was obtained. A study of the F_3 lines on the basis of mean number of days from planting to flowering substantiated the view that two important complementary factors were involved in the inheritance of earliness.

Methods and experimental results.

Detailed studies on the earliness of heading were made on two F_3 populations of reciprocal crosses between Glabron and Trebi. The emergence of awn combined with the splitting of the sheath of the first spike was taken as the criterion of heading. The number of plants heading out in each line was recorded in 2-3 day intervals during the heading period. The distribution of each line was expressed as the number of days from emergence to heading, and from this the mean of each line for the number of days from emergence to heading was calculated. The relative earliness of the lines of seven other crosses were estimated by recording the date when 10 percent of the plants were headed.

A number of observations in the field are of interest. Transgressive segregation for earliness and lateness was observed; certain hybrid lines were completely headed before any plants of the parental rows had commenced and conversely other hybrid lines did not commence heading until

David (?) studied the inheritance of earliness in crosses that is under discussion in this paper. The results obtained from other parents. When the F_2 lines were grouped on the basis of the number of days from planting to heading, a ratio of nine early to seven late was obtained. A study of the F_2 lines on the basis of mean number of days from planting to flowering substantiated the view that the important complementary factors were involved in the inheritance of earliness.

Experimental results.

Detailed studies on the earliness of heading were made on two F_2 populations of reciprocal crosses between *Albion* and *Trofi*. The emergence of ears coincided with the splitting of the sheath of the first spike was taken as the criterion of heading. The number of plants heading out in each line was recorded in 2-3 day intervals during the heading period. The distribution of each line was expressed as the number of days from emergence to heading, and from this the mean of each line for the number of days from emergence to heading was calculated. The relative earliness of the lines of seven other crosses were calculated by averaging the date when 10 percent of the plants were heading. A number of observations in the field and in the glass house. Transgressive segregation for earliness was observed; certain hybrid lines were completely headed before any plants of the parental rows had commenced heading.

the parental rows were completely headed. The parental rows were about mid-season in date of heading with Glabron approximately 3 days later than Trebi. Considerable variation existed, not only within individual lines, but between different areas in the field. Cool rainy weather occurring at heading time delayed heading in a number of the late lines. Although it has been thought that considerable care had been exercised in selecting the ^{soil for the} two populations used in this study it was found that cross 21 lay in an unproductive area of soil. This was shown by the fact that the difference in date of heading and height between Trebi and Glabron tended to be minimized. Furthermore, the lines of this cross generally matured earlier than those of other crosses. Examination of a number of the plants showed foot-rot symptoms but it is difficult to say if the unproductiveness of this area is due entirely to this disease. For the above reasons cross 21, outside of showing certain general trends, will not be of great value in the study of earliness. Approximately thirty lines of cross 12 were omitted from this study owing to the fact that they were situated on another ~~bank~~ ^{bed}, the history of whose soil varied slightly from that upon which the remainder of the cross was growing.

The distribution of the parental rows and hybrid lines, for the mean number of days from emergence to heading, of crosses 12 and 21 are given in Table XIV. The data of cross 12 are also shown in graphical form in Figure II.

the parental rows were completely headed. The parental rows were about mid-season in date of heading with Glabrous approximately 3 days later than Tread. Considerable variation in the date of heading was observed in the parental rows in different areas in the field. Cool rainy weather occurring at heading time delayed heading in a number of the late lines. Although it has been thought that considerable error had been exercised in selecting the two populations used in this study it was found that cross 21 lay in an unexpected area of soil. This was shown by the fact that the difference in date of heading and height between Tread and Glabrous failed to be minimized. Furthermore, the lines of this cross generally matured earlier than those of other crosses. Examination of a number of the plants showed root-rot symptoms but it is difficult to say if the rapidity of growth was due entirely to this disease. For the above reasons cross 21, outside of showing certain general trends, will not be of great value in the study of earliness. Approximately thirty lines of cross 12 were omitted from this study owing to the fact that they were situated on another bank, the history of whose soil varied with that from that upon which the remainder of the crosses was growing. The distribution of the parental rows and hybrids 12, for the same number of days from cross 12 to cross 12, of crosses 12 and 21 are shown in Table IV. The distribution of cross 12 is also shown in graphical form in Figure 1.

Distribution of F_3 lines[^] according to the mean number of days from emergence to heading in reciprocal crosses of Trebi and Glabron. and parental rows

Parent or cross	Classes for number of days																								Mean of variability	Coefficient		
	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71			72	
Trebi									1	1	2	2	-	1	-	1										58.88	3.56 \pm .60	
Glabron											1	2	1	1	1	-	2									61.88	3.56 \pm .60	
Cross 12 Glabron x Trebi	1	1	-	2	7	6	8	11	20	22	20	7	10	6	12	6	6	4	4	2	1	1	1	3	-	1	58.47	7.37 \pm .27
Trebi									2	1	1	1														57.30	2.11 \pm .45	
Glabron									2	-	1	2														57.60	2.35 \pm .50	
Cross 21 Trebi x Glabron				1	5	9	7	3	14	11	9	5	9	10	4	2	4	1	4	1	3	2				57.43	7.55 \pm .35	

TABLE
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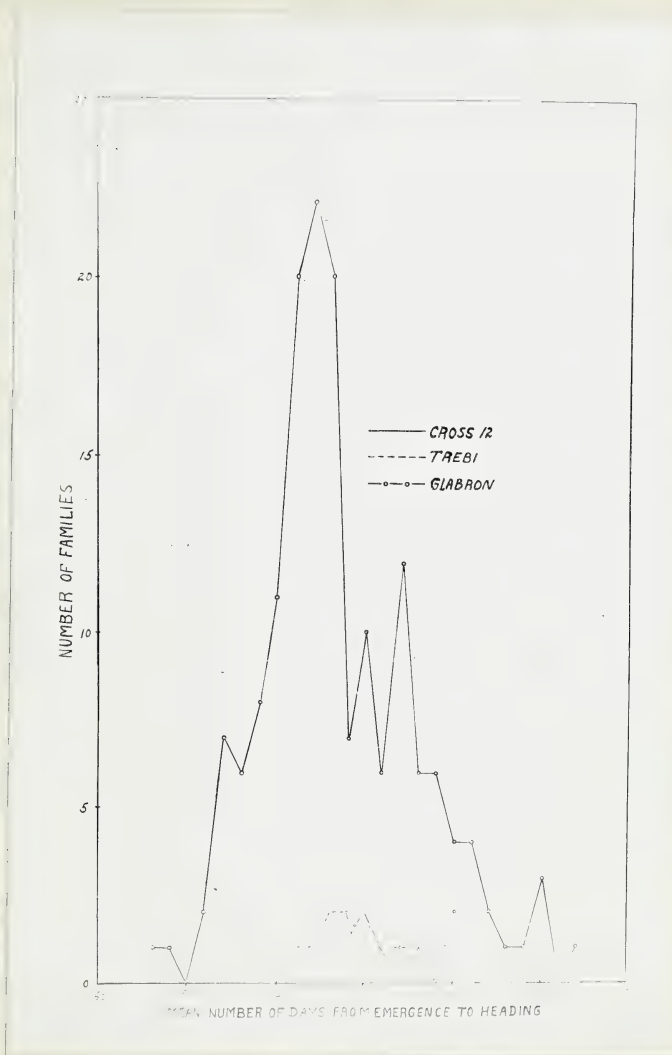


FIGURE II.

Curves showing distribution of F_3 lines and parental rows according to the mean number of days from date of emergence to heading in the cross Glabron x Trebi.

The distribution has been set out in daily intervals. Statistically, in view of the variability existing between the parental rows an interval of two days would be more accurate. The purpose in using the daily interval is an attempt to reflect as far as possible the distribution of the F_2 plants. David (7) was able to show that F_3 lines resulting from F_2 plants segregating 9:7 for early and late, were also in the ratio of 9 early : 7 late as judged by their means. A study of the curve in Figure II and the data in Table XIV reveals the fact that a distinct break occurs in cross 12 at 59 days and in cross 21 at 58 days. Using these points as an arbitrary dividing line, a good fit to 9:7 for early and late lines is obtained (Table XV).

TABLE XV.

Numbers of early and late F_3 lines as judged by their means as compared with the theoretical numbers on the basis of a 9 : 7 ratio.

Cross	Phenotypes		No. of lines		Dev.	Dev. P.E.	Odds
			Act.	Theor.			
Glabron x Tebi 12	Early		101	90.54			
		Late	60	70.42	10.42	2.45	9.89:1
Tebi x Glabron 21	Early		61	58.50			
		Late	43	45.50	2.50	0.73	<1:1

The distribution has been set out in daily intervals. Statistically, in view of the variability existing between the parental rows an interval of two days would be more appropriate. The purpose in taking the daily interval is an attempt to reflect as far as possible the distribution of the F_2 plants. David (7) was able to show that F_2 lines resulting from F_1 plants segregating 9:7 for early and late, were also in the ratio of 9 early : 7 late as judged by their means. A study of the curve in Figure II and the data in Table XIV reveals the fact that a distinct break occurs in cross 13 at 38 days and in cross 21 at 36 days. Using these points as an arbitrary dividing line, a good fit to 9:7 for early and late lines is obtained (Table XV).

TABLE XV

Numbers of early and late F_2 lines as judged by their means as compared with the theoretical numbers on the basis of a 9 : 7 ratio.

Cross	Early	Late	Total	Ratio
13	101	80	181	1.26:1
21	104	70	174	1.49:1
22	104	70	174	1.49:1
23	104	70	174	1.49:1
24	104	70	174	1.49:1
25	104	70	174	1.49:1
26	104	70	174	1.49:1
27	104	70	174	1.49:1
28	104	70	174	1.49:1
29	104	70	174	1.49:1
30	104	70	174	1.49:1
31	104	70	174	1.49:1
32	104	70	174	1.49:1
33	104	70	174	1.49:1
34	104	70	174	1.49:1
35	104	70	174	1.49:1
36	104	70	174	1.49:1
37	104	70	174	1.49:1
38	104	70	174	1.49:1
39	104	70	174	1.49:1
40	104	70	174	1.49:1
41	104	70	174	1.49:1
42	104	70	174	1.49:1
43	104	70	174	1.49:1
44	104	70	174	1.49:1
45	104	70	174	1.49:1
46	104	70	174	1.49:1
47	104	70	174	1.49:1
48	104	70	174	1.49:1
49	104	70	174	1.49:1
50	104	70	174	1.49:1
51	104	70	174	1.49:1
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53	104	70	174	1.49:1
54	104	70	174	1.49:1
55	104	70	174	1.49:1
56	104	70	174	1.49:1
57	104	70	174	1.49:1
58	104	70	174	1.49:1
59	104	70	174	1.49:1
60	104	70	174	1.49:1
61	104	70	174	1.49:1
62	104	70	174	1.49:1
63	104	70	174	1.49:1
64	104	70	174	1.49:1
65	104	70	174	1.49:1
66	104	70	174	1.49:1
67	104	70	174	1.49:1
68	104	70	174	1.49:1
69	104	70	174	1.49:1
70	104	70	174	1.49:1
71	104	70	174	1.49:1
72	104	70	174	1.49:1
73	104	70	174	1.49:1
74	104	70	174	1.49:1
75	104	70	174	1.49:1
76	104	70	174	1.49:1
77	104	70	174	1.49:1
78	104	70	174	1.49:1
79	104	70	174	1.49:1
80	104	70	174	1.49:1
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86	104	70	174	1.49:1
87	104	70	174	1.49:1
88	104	70	174	1.49:1
89	104	70	174	1.49:1
90	104	70	174	1.49:1
91	104	70	174	1.49:1
92	104	70	174	1.49:1
93	104	70	174	1.49:1
94	104	70	174	1.49:1
95	104	70	174	1.49:1
96	104	70	174	1.49:1
97	104	70	174	1.49:1
98	104	70	174	1.49:1
99	104	70	174	1.49:1
100	104	70	174	1.49:1

It was mentioned previously that the relative earliness of the lines of some seven crosses were determined by the date when 10 percent of the plants were headed. This method although of little value as far as early lines are concerned (as it takes no account of segregation for lateness) is of considerable value in the determination of the number of late lines. Estimations of the number of lines in each cross that were as late or later than the Glabron parent revealed the interesting fact that these constituted one-quarter of the total in each case. This would indicate that the late lines, comprising $7/10$ of the whole, are made up of two groups: mid-late and late. This division of the late lines is not clearly shown by the curve in Figure II, although there is a suggestion of a second mode occurring around 61-62 days.

The data indicate that two main complementary factors are involved in earliness of heading. Trebi and Glabron have been found to occupy a more or less central position on the distribution surface with Glabron a few days later than Trebi in every instance. Assuming E and L to be the factors involved in earliness of heading, the only possible genotypes of the parents based on a two-factor hypothesis would be EEll and eeLL. A casual acquaintance with the F_2 genotypes of such a combination would show that the parental lines of both Trebi and Glabron, as judged by their mean, should fall to the right of the arbitrary divisional point. An examination of the parental curves

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cross that were as late or later than the Elston parent revealed the interesting fact that these constituted one-

quarter of the total in each case. This would indicate that the late lines, comprising 7/10 of the whole, are made

up of two groups: mid-late and late. This division of the late lines is not clearly shown by the curve in Figure 11,

although there is a suggestion of a second note occurring around 61-62 days.

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with the F₂ genotypes of such a combination would show that

the parental lines of both Tremb and Elston, as far as

their mean, should fall to the right of the midpoint

of the distribution.

in Figure II shows that the parents tend to be too early. This may be partially explained by the data given in Table XV where it will be seen that, judged by their means, the early hybrid lines tend to be too numerous. Apparently, environmental conditions were such as to encourage early heading.

David (7) was able to calculate the number of homozygous early and late lines by estimating the number of lines falling completely to the left or right of an arbitrary point, dividing the early lines from the late.

A study of the frequency distributions of the individual lines, in cross 12 of the work under discussion, showed 12 lines to fall completely to the left of the arbitrary divisional point of 59 days. Since 10 such lines would be expected from the population of 160 lines used, the number obtained appears quite significant. It was impossible to determine homozygosity in the late lines as cool rainy weather prolonged the heading period.

Another interesting observation arose from the study of the distribution of individual F_3 lines in this cross. Two lines were noticed to commence heading seven days after all others had started, and conversely three lines were found to have completed the greater portion of their heading when others were showing only a few plants. As these numbers roughly approximate $1/64$ of the total population, it might be concluded that a third factor, working in conjunction with the two main complementary factors discussed above, was also involved in earliness of heading.

In Figure 11 shows that the parents tend to be too early. This may be partially explained by the data given in Table XV where it will be seen that, judged by their means, the early hybrid lines tend to be too numerous. Apparently environmental conditions were such as to encourage early heading.

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A study of the frequency distributions of the individual lines, in cross 12 of the work under discussion, showed 12 lines to fall completely to the left of the arbitrary divisional point of 50 days. Since 10 such lines would be expected from the population of 100 lines used, the number obtained appears quite significant. It was impossible to determine homogeneity in the late lines as early weather prolonged the heading period.

Another interesting observation arose from the study of the distribution of individual P_3 lines in late cross. Two lines were noticed to be homozygous for late days after all others had started, and conversely, two

of their heading when others were ahead and a few minutes. These numbers roughly approximate 1/64 of the total population. It must be concluded that a third factor, working in conjunction with the two main components, was also involved.

HEIGHT OF PLANT.

Literature review.

Vestergaard (40) reports a segregation of 14 dwarfs to 81 normal plants in the F_2 of a cross between Binder and a dwarf-like variant.

Miyake and Imai (25) crossed tall slim plants with short stout ones. The F_1 were tall and slim, whereas the F_2 segregated into a ratio of 3 tall to 1 short.

Miyayawa (26) found dwarfness tended to be dominant in a cross he studied. He also noted that the homozygous dwarfs were sterile. A segregation of one sterile dwarf to two dwarf to one normal plant was obtained in the F_2 .

Harlan and Pope (14), on the other hand, found that a dwarf form behaved as a simple recessive to the normal barley.

Neatby (27) obtained height data on 228 F_3 lines of a cross between Guy Mayle and Canadian Thorpe. No clear indication of the number of factors involved was obtained. By comparing the standard deviations of the F_3 lines with those of the parents, Neatby concluded that at least four factors seemed to be operative.

David (7) studied plant height in all three generations of crosses between Glabron x Trebi and Velvet x Trebi. The F_1 in each cross were taller than the short parent and closely approached the height of the taller. The F_2 were much more variable than the F_1 and parental forms were

Vestergaard (40) reports a segregation of 14 dwarfs
 in normal plants in the F_2 of a cross between Elmer and
 Miyake and Inai (45) crossed tall slim plants with
 short stout ones. The F_1 were tall and slim, whereas the F_2
 segregated into a ratio of 3 tall to 1 short.
 Miyake (30) found dwarfs tended to be dwarf-
 ant in a cross he studied. He also noted that the homozygous
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 David (7) studied plant height in all known land-
 race of crosses between Elmer x Inai and Inai x Elmer.
 He found that in each cross the dwarf parent was
 always associated the height of the taller. The F_2 were
 more variable than the F_1 and showed a tendency

recovered in both the F_2 and F_3 generations.

Methods and experimental results.

The two reciprocal crosses used for the study of earliness also served as a basis for a study of plant height. The criterion of height was taken as the distance from the base of the culms to the tip of the spike, excluding awns. The plants were individually pulled and measured in inches. The variability noted in regard to earliness of heading was even more striking in the case of height of plant. Again the data obtained from cross 21 could not be used in the inheritance study.

The distribution of the mean heights of the progeny and parent rows of cross 12, together with their coefficients of variability are given in Table XVI.

TABLE XVI.

Distribution of hybrid lines and parent rows for mean height in inches, in the cross Glabron x Trebi.

Parent or cross	Mean height in inches.									Mean	C.V.
	29.5	31.5	33.5	35.5	37.5	39.5	41.5	43.5	45.5		
Trebi		1	5	1	1					34.00	4.88+0.82
Glabron						2	1	4	1	42.50	4.71+0.79
Glabron x Trebi 12	1	5	25	47	38	22	19	3	-	36.91	7.74+0.29

Trebi and Glabron will be seen to differ quite strikingly in height; Trebi being on the average eight inches shorter. The coefficient of variability of the F_3 lines, as compared to that of the parents, shows that the progeny are considerably more variable than the parental rows. This would indicate a segregation of genetic factors for height of plant if the numbers of parental rows were large enough to make any conclusions possible. Judged on the basis of their mean heights, the parental rows are seen to occupy the extremes of the distribution surface, while the distribution of the progeny approaches that of the normal. Cumulative factors would appear to be involved. Since height is a character readily affected by environmental factors, it is difficult to work out any definite mode of inheritance. It will be shown later that a positive correlation of approximately 0.73 exists between number of days to heading and plant height. Although this correlation may be partially explained on a physiological basis, its high value suggests that certain of the factors involved in earliness of heading are also concerned in the expression of plant height.

Tredi and Gleason will be seen to differ quite strikingly in height; Tredi being on the average eight inches shorter. The coefficient of variability of the T_2 lines, as compared with that of the parental rows, is also strikingly different. This would indicate a segregation of genetic factors for height of plant in the numbers of parental rows were large enough to make any conclusions possible. Judged on the basis of their mean heights, the parental rows are seen to occupy the extremes of the distribution surface, while the distribution of the progeny approaches that of the normal. Quantitative factors would appear to be involved. Since height is a character readily affected by environmental factors, it is difficult to write out any definite mode of inheritance. It will be shown later that a positive correlation of approximately 0.75 exists between number of days to heading and plant height. Although this correlation may be partially explained on a physiological basis, the fact that the correlation is not 1.00 of the parental lines is evidence to suggest that the correlation is not entirely of genetic origin.

Covered Smut Reaction.

The difficulty of obtaining satisfactory infections, combined with the early development of control measures, is largely responsible for the lack of ^{genetic} investigation on ^{the} covered smut disease.

Environmental relationships.

The only work of importance regarding the effects of environment on the development of the disease in the barley plant is supplied by Faris (8,9). Using controlled conditions he was able to obtain high infection percentages on Hannchen barley over wide ranges of soil temperatures and acidity and at moistures generally existing in the soil at the time of seeding. Soil temperatures varying from 10-25°C. with 40-50% moisture content gave good infections at pH values of 5,6,7 and 7.8. In general infection was influenced unfavourably by low soil temperature and moistures at time of seeding. Acid soils with both 40 and 50 percent moisture content gave higher infections than did slightly alkaline soils. The vigor of the host plant was found to have little or no effect on the development of covered smut, although the growth conditions following infection may have a marked effect in that regard. Faris also found that the character of the soil played an important role in obtaining satisfactory infections; quartz or builder's sand gave poor results while neutral potting soil gave normal infection.

The only work of importance regarding the effect of environment on the development of the disease in the barley plant is published by Lewis (1937). Lewis controlled conditions he was able to obtain high infection percentages in Penzance barley even with ranges of soil temperatures and soil acidity and at moisture generally existing in the soil at the time of seeding. Soil temperatures varying from 10-20°C. at 40-60 cm. moisture content gave good infection at 75 values of 6.6, 7 and 7.8. In general infection was maximum and universally by low soil temperatures and moisture at the time of seeding. In soil with 40 and 60 percent moisture, infection was maximum at 7.8 and 7.5 respectively. The vigor of the host plant was found to have little or no effect on the development of the disease, although the growth conditions following infection may have a marked effect in that respect. Lewis also found that the character of the soil played an important role in the development of the disease; quartz or pebbles in the soil gave high infection; while neutral potting soil gave minimal infection.

Taylor and Zehner (35) have pointed out in the case of winter barley that greater infections resulted from deep seeding than from shallow.

The dehulled inoculated kernels used in the present inheritance study were seeded into soil with a temperature of approximately 59° F. Owing to the rather dry nature of the surface soil, the seeds were planted a little deeper than had been originally planned.

Physiologic specialization.

Faris (8) emphasized the fact that one of the important requirements necessary to produce high infection was the use of inoculum collected from the variety on which it was to be tested. This suggested the presence of physiologic forms. In a later paper, (9), he demonstrated the presence of five forms using four varieties of barley as differentials.

The writer used a composite sample of smut spores collected from Trebi, Glabron, Velvet and Comfort, in all inoculations.

Dehulling studies.

A number of investigators have found that to obtain satisfactory infections of barley with U. hordei, dehulling of the kernel is necessary.

Tisdale (36) reports that in the case of winter barley the removal of the hull resulted in greatly increased infections. He removed the hulls by means of a scalpel and concluded that some simpler method of removing the hulls was

seeding them from chaff.

The detailed inoculated kernels used in the present
inoculation study were seeded into soil with a temperature
of approximately 55° F. During the winter the nature of
the surface soil, the seeds were placed in a hole in the
soil and covered with a layer of soil.

Foris (2) emphasized the fact that one of the impor-
tant requirements necessary to produce high infection was
the use of inoculum collected from the variety on which it
was to be tested. This suggested the necessity of physi-
ologic forms. In a later paper, (3), he demonstrated the
presence of five forms having four varieties of barley as

The writer used a composite sample of such spores
collected from Thrift, Clifton, Velvet and Comfort, in all

Seedling studies.

A number of investigators have found that to obtain
satisfactory infections of barley with *V. horaei*, germination
of the kernel is necessary.

Tisdale (26) reports that in the case of barley
the removal of the hull resulted in greater infection.
He removed the hulls by means of a scupper and
employed the scupper method of removing the hulls and

necessary if extensive smut tests were to be carried out.

Faris (9) also obtained greater infections when he used inoculated dehulled seed; but found that greatly reduced stands resulted. Examination of the unemerged seed showed that practically all the kernels had commenced germination but due to distortion few were able to reach the surface.

Briggs (1) reports extensive tests carried out at Davis, California, in the years 1919-21, with hulled seed of some 570 varieties and strains. Although the seeds were heavily inoculated with viable spores little infection resulted.

Barley covered smut tests carried out at the University of Alberta in the last three years, using hulled kernels, confirms the results reported by Briggs (1).

To obtain some simple method of dehulling the barley kernel, Briggs (1) studied the possibility of using sulphuric acid. It had been previously demonstrated that the seed coat of barley was surprisingly resistant to this chemical (2). In his investigations Briggs used many different combinations of concentration of acid and duration of treatment.

The results he obtained are limited and consequently no definite conclusions can be drawn. Fortunately, the hull over the germ was found to be thicker than elsewhere, on the kernel and a thin covering often remained over the germ when the remainder of the kernel was completely dehulled. There appeared to be considerable variations in smut infection after apparently equal degrees of dehulling; due probably to the small numbers of plants used.

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the kernel and a thin covering of the embryo were found
germ when the remainder of the kernel was removed by de-
hulling. There appeared to be considerable variation in
but infection after apparently equal periods of treatment.

Low concentrations of acid for a long period of time gave infections comparable to high concentrations for short periods of time. A certain amount of corrosion of the kernels was noted when the more concentrated acid was used. It was also observed that complete dehulling was not necessary for good infection; in fact a thin hull over the entire kernel seem to give better results. In general it may be said that this sulphuric acid method gave results comparing very favourably with seed dehulled by hand and offered a promising means of testing hybrid populations for smut reaction.

The method just described was utilized, in modified form, to dehull the kernels of the hybrid and parental lines used in the present inheritance studies. Since no conclusive evidence as to the optimum strength of acid and duration of treatment can be drawn from Briggs' investigation, and since there is ample room for further and special investigations in this regard, it was decided to use only the concentrated sulphuric acid.

Preliminary trials, not reported in this paper, showed that exposure to concentrated acid for a period of 4-5 minutes had little deleterious effect on the germination of kernels of Glabron and Trebi, the parents of the hybrids under study. In fact, a thin hull remained over the greater part of the kernel. To facilitate the treatment of the kernels of a large number of F_2 plants the apparatus shown in Figure III was devised.

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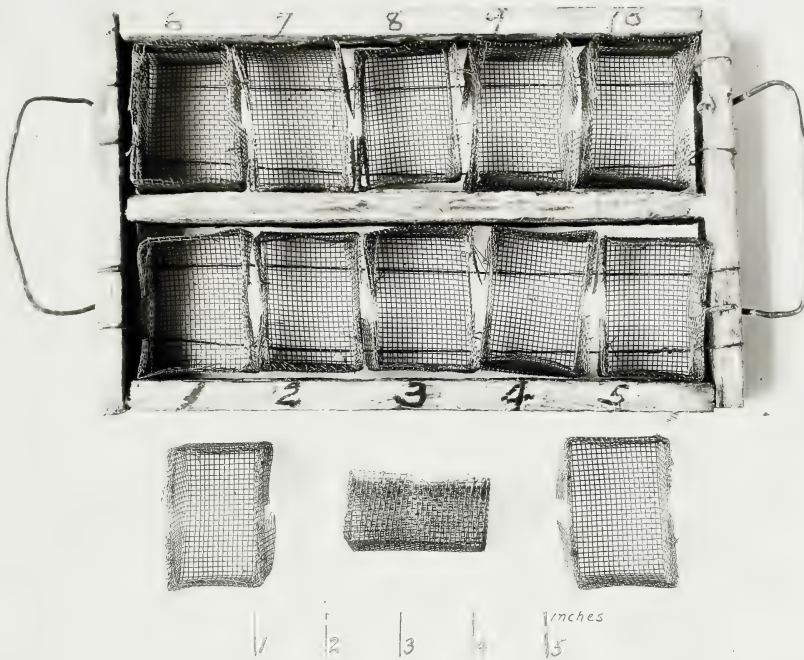


FIGURE III.

Immersion tray (including wire baskets) used
in the dehulling of barley kernels by the
sulphuric acid method.

This apparatus consists of a tray composed of a wooden frame coated with paraffin, and two strands of copper wire serving as a support for two rows of bronze netted-wire baskets. The identity of the latter is kept by a number found opposite them on the frame. The method utilized in dehulling the kernels of the parental materials will serve to illustrate the general technique adopted, while a modified method used in dehulling the kernels of the hybrid lines will be described later.

The number of the basket into which the kernels are placed is written on the envelope from which the kernels were taken, thus insuring that the identity of the sample will not be lost. The tray containing the ten samples is immersed in the concentrated acid for a period of approximately five minutes, then removed and plunged quickly into cold water. Here the kernels are washed vigorously for about two minutes. To counteract any acid that might still remain on the kernels the tray is immersed in a concentrated solution of NaHCO_3 (baking soda) for a period of 2-3 minutes. The kernels are then washed a second time before being placed on blotting paper to dry. After drying the samples are returned to their original envelopes.

After this treatment the majority of the kernels were found to be completely dehulled except for a thin hull remaining over the embryo.

During this operation it was found that if kernels which had been treated for a short time were washed ^{in water} and then returned to the acid for only a few seconds, rapid and

The apparatus consists of a tray composed of a wooden frame
covered with paraffin, and two strands of copper wire serving
as a support for two rows of brown netted-wire baskets.
The identity of the latter is kept by a number found opposite
the name of the sample. The whole apparatus is placed in a
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tion of sodium bicarbonate (soda) for a period of 2-3 minutes.
The kernels are then washed in cold water for about five minutes
on blotting paper to dry. After drying the samples are
returned to their original envelopes.

After this treatment the majority of the kernels
will be completely denuded except for a thin film
covering over the embryo.

complete dehulling resulted. Germination tests run in the laboratory showed only slight reductions in germination of the treated kernels as compared to the normal. The degree of dehulling was as complete as that produced by the five minute method and the injury appeared to be less. The method appeared so promising in the light of the germination tests that it was decided to utilize it in the dehulling of the kernels of the hybrid lines. The technique of both methods was essentially the same except that in the modified method, the tray was removed from the acid after two minutes, washed with cold water, and replaced in the acid for the brief period of ten seconds.

A number of precautions had to be taken. Only five or six trays of kernels could be treated in one lot of acid as the digested portions of the hull rendered the acid less effective. It was also observed that when more than fifty kernels were placed in a basket less uniform results were obtained; certain of the kernels escaping normal treatment. Severely threshed kernels showed considerable corrosion ; the germ often being partially digested.

Criticism may be directed at this phase of the work in that different methods were used in dehulling the parental and the hybrid materials, respectively. Preliminary tests showed that the degree of dehulling and the amount of injury resulting from these two methods varied but slightly. Briggs (1) has pointed out that complete dehulling is not necessary for optimum infection. With this in mind it can be concluded that slight variations in the degree of

complete dehulling resulted. Germination tests run in the laboratory showed only slight reductions in germination of the treated kernels as compared to the normal. The degree of dehulling was as complete as that produced by the five minute method and the injury appeared to be less. The method appeared so promising in the light of the germination tests that it was decided to utilize it in the dehulling of the kernels of the hybrid lines. The technique of both methods was essentially the same except that in the modified method, the tray was removed from the acid after two minutes, washed with cold water, and replaced in the acid for the balance of ten seconds. A number of precautions had to be taken. Only five or six trays of kernels could be treated in one lot of acid as the digested portions of the hull rendered the acid less effective. It was also observed that when more than fifty kernels were placed in a basket less uniform results were obtained. Severely thrashed kernels showed considerable corrosion; the germ often being partially digested. Criticism may be directed at this phase of the work in that different methods were used in dehulling the normal and the hybrid materials, respectively. Preliminary tests showed that the degree of dehulling and the amount of injury resulting from these two methods varied but slightly. Briggs (1) has pointed out that complete dehulling is not necessary for optimum infection. With this in mind it was

dehulling will have little or no effect on the percentage of smut finally appearing on the plants ^{from} ~~of~~ such kernels.

As it has been pointed out previously the dehulled kernels were heavily inoculated with a composite sample of covered smut spores and seeded rather deeply into soil of a temperature approximately 59°F. Unfortunately no rain fell for a period of 7-8 days following seeding. The emergence of the seedlings was very ununiform until the advent of rain after which a considerable number of seeds were stimulated to germinate. Notwithstanding this additional germination, a study of parental and hybrid lines showed disappointing results. Large unaccountable fluctuations occurred, for lines with only fifteen plants were bordered by lines containing thirty-five plants.

As the number of kernels ^{from} per line was only approximated, the average percentage germination cannot be definitely given. A rough estimation would place the mortality between 40-50 percent.

The fluctuation in the parental rows was also very evident. Check rows of Glabron showed a germination range from 15-47 plants. Trebi exhibited even more variability due in part to the slower germination of the kernels thus allowing a greater opportunity for attack by mould fungi. Ten consecutive rows of Trebi (the contents of tray) showed very low germination percentages. This is difficult to explain when it was thought that identical treatment had been given each lot of kernels.

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... given each lot of kernels.

An examination of a number of the lines low in germination revealed the fact that in the majority of cases germination had commenced, but due to either the direct weakening effects of the acid or to the indirect effect of dehulling which predisposed the young seedlings to a number of adverse environmental factors, the seedlings ^{were} ~~was~~ unable to reach the soil surface. Faris (9) found the kernels dehulled by hand and inoculated with covered smut spores germinated normally but ^{the seedlings} ~~were~~ so distorted as to be unable to reach the soil surface. This is undoubtedly due to the creation of a more favourable condition for the smut fungus and a consequent greater infection of the young seedlings. A large number of the unemerged seedlings, examined in the present study, had made good progress in growth but due to extreme distortion had been unable to reach the soil surface (see Figure IVb). This would indicate that the failure to emerge in the case of these seedlings was due more to the greater opportunity of infection afforded the smut fungus than to any direct injury by the acid.

Other seedlings were found whose germination processes were early arrested by certain blue mould fungi. (See Figure IVc). It is highly probable that had environmental conditions been a little more favourable these seedlings would have evaded such fungi.

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Other seedlings were found whose germination
processes were early arrested by certain lime mould fungi.
(see Figure IVd). It is highly probable that had environmental
conditions been a little more favorable these seedlings
would have avoided such fungi.



FIGURE IV.

Injured barley seedlings, resulting from kernels dehulled by sulphuric acid and followed by inoculation with the spores of Ustilago hordei.

- A. Healthy seedlings resulting from non-dehulled uninoculated kernels.
- B. Distorted seedlings resulting from dehulled, inoculated kernels.
- C. Seedlings from kernels treated identically with B, showing distortion and stunting as a result of attack by mould fungi shortly after germination.

Unfortunately, no dehulled uninoculated rows were seeded, so that it is impossible to state just what proportion of the injury is due to the acid and what proportion is due to severe infection by the smut fungus. Since no infection occurred in the loose smut nursery, it would seem that a comparison of the duplicate lines in these nurseries might throw some light on the problem. It has already been mentioned that the ^{number of} kernels ^{sown} for each line ~~were~~ ^{was} only approximated. This difficulty, combined with the fact that owing to contamination of the loose smut inoculum scattered infection with covered smut, occurred; a direct comparison is not possible. A study of duplicate lines in the two nurseries revealed a general parallelism in the degree of injury. However, here again great variations occurred.

The kernels of a number of standard varieties were dehulled by the method outlined for the hybrid lines. Certain differences were noted in the amount of dehulling occurring between those varieties. The field germination together with the infection percentages for each variety ^{are} ~~is~~ given in Table XVII.

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The kernels of a number of standard varieties were
analyzed by the method outlined for the hybrid lines. Certain
differences were noted in the amount of denuding occurring
between these varieties. The field examination together
with the infection percentages for each variety is given
in Table XVII.

TABLE XVII.

Percentage germination and infection with covered smut in 29 varieties of barley grown from seed treated with concentrated sulphuric acid, and inoculated with spores of U. hordei.

Variety	* N.S.N.	No. of Plants	No. infect- ed	% infect- ed
Trebi	I-27-7	36	9	25.0
O.A.C.	I-29-3	42	1	2.4
Bearer	I-27-6	23	2	8.7
Star	I-30-3	10	2	20.0
Manchurian	I-0-1	29	16	55.2
Minsturdi	I-28-16	26	2	7.7
Peatland	I-28-18	17	4	23.5
Legal	I-29-2	42	7	16.7
Sacramento	I-31-1	10	0	0.0
Vaughn	I-31-3	29	6	20.7
Olli	I-32-2	32	6	18.8
Colsess	I-29-1	35	3	8.6
Sol	I-31-5	16	2	12.5
Glabron	I-28-15	38	0	0.0
Velvet	I-28-35	36	1	2.8
Comfort	I-30-2	41	4	9.8
Wis. Ped. 38	I-31-1	23	2	8.7
Harrington Sel.	I-25-5	9	0	0.0
265 x O.A.C.21	H-19-146	25	7	25.9
Canadian Thorpe	I-0-3	14	1	7.1
" " (decid.)	S-29-2	30	0	0.0
Horn	I-27-4	48	1	2.1
Charlottetown	I-27-2	20	9	45.0

Investigation and collection of material with covered
and in the collection of material from the
with concentrated sulphuric acid.
The material is in the form of a solid.

Serial	Weight	Volume	Temperature	Remarks
1	1.0	1.0	25.0	Test
2	1.0	1.0	25.0	O.A.C.
3	1.0	1.0	25.0	Test
4	1.0	1.0	25.0	Test
5	1.0	1.0	25.0	Test
6	1.0	1.0	25.0	Test
7	1.0	1.0	25.0	Test
8	1.0	1.0	25.0	Test
9	1.0	1.0	25.0	Test
10	1.0	1.0	25.0	Test
11	1.0	1.0	25.0	Test
12	1.0	1.0	25.0	Test
13	1.0	1.0	25.0	Test
14	1.0	1.0	25.0	Test
15	1.0	1.0	25.0	Test
16	1.0	1.0	25.0	Test
17	1.0	1.0	25.0	Test
18	1.0	1.0	25.0	Test
19	1.0	1.0	25.0	Test
20	1.0	1.0	25.0	Test
21	1.0	1.0	25.0	Test
22	1.0	1.0	25.0	Test
23	1.0	1.0	25.0	Test
24	1.0	1.0	25.0	Test
25	1.0	1.0	25.0	Test
26	1.0	1.0	25.0	Test
27	1.0	1.0	25.0	Test
28	1.0	1.0	25.0	Test
29	1.0	1.0	25.0	Test
30	1.0	1.0	25.0	Test
31	1.0	1.0	25.0	Test
32	1.0	1.0	25.0	Test
33	1.0	1.0	25.0	Test
34	1.0	1.0	25.0	Test
35	1.0	1.0	25.0	Test
36	1.0	1.0	25.0	Test
37	1.0	1.0	25.0	Test
38	1.0	1.0	25.0	Test
39	1.0	1.0	25.0	Test
40	1.0	1.0	25.0	Test
41	1.0	1.0	25.0	Test
42	1.0	1.0	25.0	Test
43	1.0	1.0	25.0	Test
44	1.0	1.0	25.0	Test
45	1.0	1.0	25.0	Test
46	1.0	1.0	25.0	Test
47	1.0	1.0	25.0	Test
48	1.0	1.0	25.0	Test
49	1.0	1.0	25.0	Test
50	1.0	1.0	25.0	Test
51	1.0	1.0	25.0	Test
52	1.0	1.0	25.0	Test
53	1.0	1.0	25.0	Test
54	1.0	1.0	25.0	Test
55	1.0	1.0	25.0	Test
56	1.0	1.0	25.0	Test
57	1.0	1.0	25.0	Test
58	1.0	1.0	25.0	Test
59	1.0	1.0	25.0	Test
60	1.0	1.0	25.0	Test
61	1.0	1.0	25.0	Test
62	1.0	1.0	25.0	Test
63	1.0	1.0	25.0	Test
64	1.0	1.0	25.0	Test
65	1.0	1.0	25.0	Test
66	1.0	1.0	25.0	Test
67	1.0	1.0	25.0	Test
68	1.0	1.0	25.0	Test
69	1.0	1.0	25.0	Test
70	1.0	1.0	25.0	Test
71	1.0	1.0	25.0	Test
72	1.0	1.0	25.0	Test
73	1.0	1.0	25.0	Test
74	1.0	1.0	25.0	Test
75	1.0	1.0	25.0	Test
76	1.0	1.0	25.0	Test
77	1.0	1.0	25.0	Test
78	1.0	1.0	25.0	Test
79	1.0	1.0	25.0	Test
80	1.0	1.0	25.0	Test
81	1.0	1.0	25.0	Test
82	1.0	1.0	25.0	Test
83	1.0	1.0	25.0	Test
84	1.0	1.0	25.0	Test
85	1.0	1.0	25.0	Test
86	1.0	1.0	25.0	Test
87	1.0	1.0	25.0	Test
88	1.0	1.0	25.0	Test
89	1.0	1.0	25.0	Test
90	1.0	1.0	25.0	Test
91	1.0	1.0	25.0	Test
92	1.0	1.0	25.0	Test
93	1.0	1.0	25.0	Test
94	1.0	1.0	25.0	Test
95	1.0	1.0	25.0	Test
96	1.0	1.0	25.0	Test
97	1.0	1.0	25.0	Test
98	1.0	1.0	25.0	Test
99	1.0	1.0	25.0	Test
100	1.0	1.0	25.0	Test

Table XVII (Continued).

Variety	N.S.N.*	No. of plants	No. infect- ed	% infect- ed
Hannchen	I-27-1	14	5	35.7
Duckbill	I-30-5	10	3	30.0
Gold	I-28-5	9	1	11.1
Alberta Beardless	S-29-1	12	1	8.3
Success	I-32-4	26	0	0.0
Spartan	I-28-20	15	2	13.3

* Nursery stock number.

The data presented in the above table would indicate that definite differences exist in the ability of the kernels of certain varieties to germinate after acid treatment. Since the kernels of some varieties were more susceptible to threshing injury than were others, it is difficult to say whether the injury was due to a greater susceptibility of the hull to acid, or to the embryos of the kernels being unprotected. The great reduction in germination of the kernels of two varieties of barley, after treatment with acid and inoculated with spores of U. hordei, is shown in Figure V. The retardation of growth of the plants from treated kernels is also quite evident. Figure VI shows certain apparent varietal differences in the ability of barley kernels to germinate after acid treatment and inoculation with spores of U. hordei.

Table XVII (Continued).

Variety	U.S.D.A. No.	No. of plants	Inoculated	Inoculated
Hannchen	1-37-1	14	5	35.7
Broccoli	1-30-5	10	3	30.0
Gold	1-36-5	9	1	11.1
Alfalfa	1-37-2	12	1	8.3
Guinness	1-38-4	30	0	0.0
...	1-38-30	15	2	13.3

* Nursery stock number.

The data presented in the above table would indicate that definite differences exist in the ability of the kernels of certain varieties to germinate after acid treatment. Since the kernels of some varieties were more susceptible to this injury than were others, it is difficult to say whether the injury was due to a greater susceptibility of the hull to acid, or to the embryo of the kernels being unprotected. The great reduction in germination of the kernels of two varieties of barley, after treatment with acid and inoculated with spores of *U. hordei*, is shown in Figure V. The retention of growth of the plants from treated kernels is also quite evident. Figure VI shows certain apparent varietal differences in the ability of barley kernels to germinate after acid treatment and inoculation with spores of *U. hordei*.



FIGURE V.

Effects of dehulling the kernels of two varieties of barley with H_2SO_4 , followed by inoculation with the spores of *U. hordei*, upon emergence and vigor of growth of the barley seedlings.

Left to right:

- Colsess - hulled, uninoculated.
- Colsess - dehulled, inoculated.
- Spartan - hulled, uninoculated.
- Spartan - dehulled, inoculated.
- Eureka - naturally hullless, uninoculated.

(Note the stunting effect of the acid on the plants in the treated rows).



FIGURE VI.

The effects upon the germination of kernels of four varieties of barley, when dehulled by acid and inoculated with spores of Ustilago hordei.

Five central rows, left to right:

New Era - naturally hulless.
Olli - dehulled by acid.
Vaughn - dehulled by acid.
Sacramento - dehulled by acid.
Regal - dehulled by acid.

In an endeavor to determine just what factors were responsible for the lack of emergence noted in dehulled inoculated lines, a number of greenhouse experiments were conducted. The modified acid treatment was used on several varieties. Certain minor variations between varieties will be observed but owing to the small number of kernels used, only totals or averages will show reliable trends. An experiment was outlined in an attempt to find out whether or not the reduction in germination could be explained in part by the greater opportunity of infection afforded the pathogene by the dehulled seed. For this purpose uninoculated and inoculated lots of normal kernels, kernels dehulled by hand and kernels dehulled by acid, were seeded in unsterilized soil. The results are laid out in Table XVIII.

Two conclusions may be drawn. In the first place kernels dehulled by acid gave much lower germination than kernels dehulled by hand. In the second place, whereas there is no difference in the percentage germination of uninoculated and inoculated, hulled kernels; there is considerable difference in this regard, in the dehulled lots. This fact is especially significant in case of the kernels dehulled by hand, and would indicate that reduction in germination of dehulled inoculated kernels is due in part to the severe infection of the seedlings by the pathogene.

In an endeavor to determine just what factors were responsible for the lack of emergence noted in dehusked kernels, a number of greenhouse experiments were conducted. The modified acid treatment was used on several varieties. Certain minor variations between varieties will be observed but owing to the small number of kernels used, only totals or averages will show reliable trends. An experiment was outlined in an attempt to find out whether or not the reaction in germination could be explained in part by the greater opportunity of infection afforded the pathogen by the dehusked seed. For this purpose uninoculated and inoculated lots of normal kernels, kernels dehusked by hand and kernels dehusked by acid, were seeded in unsterilized soil. The results are laid out in Table XVII.

Two conclusions may be drawn. In the first place kernels dehusked by acid gave much lower germination than kernels dehusked by hand. In the second place, whereas there is no difference in the percentage germination of uninoculated and inoculated, hulled kernels; there is considerable difference in this regard, in the dehusked lots. This fact is especially significant in case of the kernels dehusked by hand, and would indicate that reduction in germination of dehusked inoculated kernels is due in part to the severe infection of the seedlings by the pathogen.

TABLE XVIII.

Percent germination of 5 varieties of barley hulled, dehulled by hand, and by H_2SO_4 when inoculated with spores of Ustilago hordei.

Variety	Normal hulled		Dehulled by hand		Dehulled by acid(mod.)	
	Uninoc.	Inoc.	Uninoc.	Inoc.	Uninoc.	Inoc.
	% germ.	% germ.	% germ.	% germ.	% germ.	% germ.
Glabron	93.3	80.0	90.0	76.7	50.0	40.0
Trebi	86.7	86.7	83.3	80.0	43.3	33.3
Bearer	90.0	90.0	100.0	80.0	60.0	53.3
Harrington Sel. I-25-5	86.7	80.0	96.7	63.3	30.0	20.0
O.A.C. No.21	93.3	96.7	66.7	46.7	33.3	23.3
Average	88.0	86.7	87.3	69.3	43.3	36.6

As blue mould fungi were found to be complicating the results in the field; it was decided to run a test on both sterilized and unsterilized soils. In this experiment uninoculated and inoculated lots of both hulled and acid-dehulled kernels were used. The results as summarized in Table XIX show that the uninoculated and inoculated hulled kernels germinated equally well ~~on~~ both sterilized and unsterilized soil.

TABLE III

Percent germination of 3 varieties of barley hulls, as determined by hand, and by H₂O₂, when inoculated with spores of *Helicium hirsutum*.

Barley	Hulls	by hand	by H ₂ O ₂	by hand	by H ₂ O ₂
Alameda	88.0	88.7	88.7	88.7	88.7
Trebit	88.7	88.7	88.7	88.7	88.7
Barley	88.7	88.7	88.7	88.7	88.7
Harrington Sel. I-88-8	88.7	88.7	88.7	88.7	88.7
U.S. No. 1	88.7	88.7	88.7	88.7	88.7
Average	88.0	88.7	88.7	88.7	88.7

As blue mould fungi were found to be complicating the results in the trials; it was decided to run a test on both sterilized and unsterilized soils. In this experiment uninoculated and inoculated lots of both hulls and solid-barley kernels were used. The results as summarized in Table IV show that the uninoculated and inoculated hulls and kernels germinated equally well on both sterilized and unsterilized

TABLE XIX.

Germination of H_2SO_4 dehulled kernels of 7 varieties of barley when inoculated with spores of Ustilago hordei and sown in sterilized and unsterilized soil.

Variety	Sterilized Soil				Unsterilized Soil			
	Hulled		Dehulled		Hulled		Dehulled	
	Uninoc.	Inoc.	Uninoc.	Inoc.	Uninoc.	Inoc.	Uninoc.	Inoc.
O.A.C.No.21	12	14	8	8	15	13	13	6
Hannechen	12	14	10.	8	14	13	6	1
Trebi	13	13	8	7	14	13	9	3
Canadian Thorpe	12	14	5	5	12	12	2	4
Peatland	14	14	12	11	11	13	5	2
Gold	15	12	8	8	14	14	9	7
Glabron	15	12	4	4	15	15	3	1
Total germination	95	93	55	51	95	93	47	24

There is a greater reduction in germination from dehulled kernels (both uninoculated and inoculated) when grown on unsterilized soil than when grown on sterilized. Probably the most striking fact shown by the data in Table XIX is that , whereas the dehulled uninoculated and inoculated kernels show little difference in germination on sterile~~d~~ soil, they exhibit quite a marked difference in this regard on unsterilized soil; the inoculated kernels being much lower in germination. This is difficult to explain unless it is assumed that conditions existing in the unsterilized soil favour severe infection of the barley seedling by the pathogene.

TABLE III

Germination of corn seedlings in soil treated with formalin, in relation to the amount of formalin used and the time of treatment.

Variety	Soil treated with formalin		Soil not treated with formalin		Total	
	Formalin	Germination	Formalin	Germination	Formalin	Germination
O.A.C. No. 21	12	14	8	8	12	12
Hannover	12	14	10	8	12	14
Trebil	12	12	8	7	12	12
Canadian Thorpe	12	14	5	5	12	12
Freedom	12	14	11	11	12	12
Cold	12	12	8	8	12	12
Glinson	12	12	4	4	12	12
Total germination	96	96	58	51	96	96

There is a greater reduction in germination than detailed in kernels (both unincubated and incubated) when grown on unsterilized soil than when grown on sterilized. Probably the most striking fact shown by the data in Table III is that unsterilized, formalin unincubated and incubated kernels show little difference in germination on sterile soil, they exhibit quite a marked difference in this regard on unsterilized soil; the incubated kernels being much lower in germination than the unincubated kernels. This is difficult to explain unless it is assumed that conditions existing in the unsterilized soil favour severe infection of the barley seedling by the pathogen.

The injury resulting from treating severely threshed kernels is plainly evident from the data given in Table XX.

TABLE XX.

Percent germination of severely threshed kernels of 4 varieties of barley when treated with H_2SO_4 .

Variety	Random sample		Severely threshed	
	Non-treated	Treated	Non-treated	Treated
	% germ.	% germ.	% germ.	% germ.
O.A. C. No.21	93.3	63.3	86.7	0.0
Canadian Thorpe	93.3	43.3	83.3	0.0
Wisconsin Pedigree No.38	100.0	90.0	93.3	0.0
Harrington Sel. I-25-5	100.0	50.0	53.3	3.3
Average	96.7	61.7	79.2	0.8

The kernels described as "severely threshed" were made up of only those individuals showing a split or break of the hull over the embryo; no completely dehulled kernels being treated.

Summarizing the dehulling experiments briefly, it may be said that unaccountable fluctuations in field germination resulted from what appeared to be equal degrees of acid treatment. Field and greenhouse observations show a number of factors to be concerned in reduction of germination. The direct inability of the kernels to withstand the acid treatment is doubtlessly an important factor. Almost as important

The injury resulting from thrashing severely thrashed
ed kernels is plainly evident from the data given in Table III.

Percent germination of severely thrashed kernels
of 4 varieties of barley when thrashed in 1934.

Percent germination	Percent germination	Percent germination	Percent germination	Percent germination
0.0	38.7	35.3	35.3	O.A. C. No. 21
0.0	38.3	48.3	35.3	Canadian Thorpe
0.0	38.3	30.0	100.0	Wisconsin Pedigree No. 38
3.3	38.3	30.0	100.0	Harrington 301. 1-33-2
0.0	79.2	61.7	96.7	Average

The kernels described as "severely thrashed" were made up of
only those individuals showing a split or break of the hull
over the embryo; no completely denuded kernels being treated.
Summarizing the denuding experiments briefly, it
may be said that unaccountable fluctuations in field germina-
tion resulted from what appeared to be equal degrees of acid
treatment. Field and greenhouse observations show a number
of factors to be concerned in reduction of germination. The
most important of these factors is undoubtedly an important
factor in the reduction of germination.

is the practice of treating kernels exhibiting mechanical damage. After seeding, the attack by certain blue mould fungi, as well as increased infection by the pathogene, are instrumental in reducing the number of plants reaching the soil surface.

Genetic studies.

As far as the writer is aware no work of a genetic nature has appeared in the literature.

In the study to be reported the reactions of the lines of nine crosses, involving Glabron and Trebi, to the covered smut disease were determined. Considerable variation in the severity of infection of individual plants was noted (Figure VII). This was due to the fact that the first spikes to emerge from the sheath tended to escape infection. Infected culms were found to be slower in heading than the healthy ones, and in some cases the smutted spikes, rather than pushing their way through the top of the sheath, simply forced their way through the base. In one or two cases the peduncle bearing the smutted spike was badly distorted (Figure VII). In no cases did the leaves show smut pustules as was observed by Faris (8) in the case of severely infected plants.

is the question of treating bacteria exhibiting mechanical damage. After seedling, the attack by certain lines would be reduced, as well as increased infection by the pathogen, and instrumental in reducing the number of plants showing the soil surface.

Genetic studies.

As far as the writer is aware no work of a genetic nature has appeared in the literature. In the study to be reported the reactions of the lines of nine crosses, involving Gladston and Trebil, to the covered smut disease were determined. Considerable variation in the severity of infection of individual plants was noted (Figure VII). This was due to the fact that the first spikes to emerge from the sheath tended to escape infection. Infected culms were found to be slower in heading than the healthy ones, and in some cases the smutted spikes, rather than pushing their way through the top of the sheath, simply forced their way through the base. In some cases the peduncle bearing the smutted spike was badly distorted (Figure VII). In no cases did the leaves show any distortion or any other evidence of damage.



FIGURE VII .

Barley plants infected with covered smut, Ustilago hordei.

Left to right:

Normal plant.

Totally smutted plant, with the spikes just emerging from the sheaths. (Note the distortion of the peduncle).

Totally smutted plant, with spikes fully emerged.

Partially smutted plant, showing one normal spike and one smutted only at the base.

All plants exhibiting any degree of infection were called susceptible. The percentage infection was calculated for all lines containing fifteen or more plants and the lines were grouped in classes according to the percentage infection. A class interval of 10 percent was used. A zero class was added to include all lines showing no infection.

The reaction of F_3 lines and parental varieties to the covered smut disease is supplied by the data given in Table XXI. The Glabron parent appears highly resistant while the Trebi may be classed as moderately susceptible. The wide range of infection percentages exhibited by the Trebi parent would indicate that infection had not been altogether satisfactory. With this fact in mind, it is not altogether surprising that the hybrids do not lend themselves to factorial analysis. The progeny exhibit high resistance; there being little evidence of transgression toward greater susceptibility.

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called susceptible. The percentage infection was calculated
for all lines containing fifteen or more plants and the lines
were grouped in classes according to the percentage infection.
A class interval of 10 percent was used. A zero
class was added to include all lines showing no infection.
The reaction of F₂ lines and parental varieties
to the covered seed disease is supplied by the data given
in Table XXI. The Cispren parent appears highly resistant
while the Trebi may be classed as moderately susceptible.
The wide range of infection percentages exhibited by the
Trebi parent would indicate that infection had not been
altogether satisfactory. With this fact in mind, it is not
altogether surprising that the hybrids do not tend them-
selves to factorial analysis. The progeny exhibit high
resistance; there being little evidence of transgression

TABLE XXI.

Reaction of F_3 lines and parental varieties to
Ustilago hordei in reciprocal crosses of
Glabron and Trebi.

Parent or cross		Infection classes in percentage						
		0	5	15	25	35	45	55
Trebi		-	2	11	8	4	2	-
Glabron		9	24	2	-	-	-	-
Glabron x Trebi	6	2	14	10	6	1	1	-
	11	-	8	29	18	11	3	-
	12	13	49	37	10	6	3	2
	13	22	33	22	14	3	2	1
Trebi x Glabron	19	2	21	10	7	6	4	1
	20	4	11	24	10	8	4	1
	21	-	15	13	14	12	3	3
	23	-	6	11	17	10	9	1
	45	20	17	24	7	1	1	-
Total		63	174	180	103	58	30	9

TABLE 1

of selected varieties of cotton in the State of Texas, 1911-1912

Variety	Yield per acre, bales						Total
	1911	1912	1913	1914	1915	1916	
Upland	1.2	1.1	1.0	0.9	0.8	0.7	6.7
Pima	1.5	1.4	1.3	1.2	1.1	1.0	8.5
Sea Island	1.8	1.7	1.6	1.5	1.4	1.3	10.3
Staple	1.6	1.5	1.4	1.3	1.2	1.1	9.1
Long-staple	1.4	1.3	1.2	1.1	1.0	0.9	7.9
Short-staple	1.2	1.1	1.0	0.9	0.8	0.7	6.7
Extra-long-staple	1.0	0.9	0.8	0.7	0.6	0.5	5.5
Superior	1.1	1.0	0.9	0.8	0.7	0.6	6.1
Delaware	1.3	1.2	1.1	1.0	0.9	0.8	7.3
Georgia	1.4	1.3	1.2	1.1	1.0	0.9	7.9
Florida	1.5	1.4	1.3	1.2	1.1	1.0	8.5
Alabama	1.6	1.5	1.4	1.3	1.2	1.1	9.1
Mississippi	1.7	1.6	1.5	1.4	1.3	1.2	9.7
Louisiana	1.8	1.7	1.6	1.5	1.4	1.3	10.3
Arkansas	1.9	1.8	1.7	1.6	1.5	1.4	10.9
Oklahoma	2.0	1.9	1.8	1.7	1.6	1.5	11.5
Nebraska	2.1	2.0	1.9	1.8	1.7	1.6	12.1
Kansas	2.2	2.1	2.0	1.9	1.8	1.7	12.7
Colorado	2.3	2.2	2.1	2.0	1.9	1.8	13.3
Utah	2.4	2.3	2.2	2.1	2.0	1.9	13.9
Idaho	2.5	2.4	2.3	2.2	2.1	2.0	14.5
Montana	2.6	2.5	2.4	2.3	2.2	2.1	15.1
Wyoming	2.7	2.6	2.5	2.4	2.3	2.2	15.7
North Dakota	2.8	2.7	2.6	2.5	2.4	2.3	16.3
South Dakota	2.9	2.8	2.7	2.6	2.5	2.4	16.9
Minnesota	3.0	2.9	2.8	2.7	2.6	2.5	17.5
Wisconsin	3.1	3.0	2.9	2.8	2.7	2.6	18.1
Illinois	3.2	3.1	3.0	2.9	2.8	2.7	18.7
Indiana	3.3	3.2	3.1	3.0	2.9	2.8	19.3
Ohio	3.4	3.3	3.2	3.1	3.0	2.9	19.9
Michigan	3.5	3.4	3.3	3.2	3.1	3.0	20.5
Wisconsin	3.6	3.5	3.4	3.3	3.2	3.1	21.1
Illinois	3.7	3.6	3.5	3.4	3.3	3.2	21.7
Indiana	3.8	3.7	3.6	3.5	3.4	3.3	22.3
Ohio	3.9	3.8	3.7	3.6	3.5	3.4	22.9
Michigan	4.0	3.9	3.8	3.7	3.6	3.5	23.5
Wisconsin	4.1	4.0	3.9	3.8	3.7	3.6	24.1
Illinois	4.2	4.1	4.0	3.9	3.8	3.7	24.7
Indiana	4.3	4.2	4.1	4.0	3.9	3.8	25.3
Ohio	4.4	4.3	4.2	4.1	4.0	3.9	25.9
Michigan	4.5	4.4	4.3	4.2	4.1	4.0	26.5
Wisconsin	4.6	4.5	4.4	4.3	4.2	4.1	27.1
Illinois	4.7	4.6	4.5	4.4	4.3	4.2	27.7
Indiana	4.8	4.7	4.6	4.5	4.4	4.3	28.3
Ohio	4.9	4.8	4.7	4.6	4.5	4.4	28.9
Michigan	5.0	4.9	4.8	4.7	4.6	4.5	29.5
Wisconsin	5.1	5.0	4.9	4.8	4.7	4.6	30.1
Illinois	5.2	5.1	5.0	4.9	4.8	4.7	30.7
Indiana	5.3	5.2	5.1	5.0	4.9	4.8	31.3
Ohio	5.4	5.3	5.2	5.1	5.0	4.9	31.9
Michigan	5.5	5.4	5.3	5.2	5.1	5.0	32.5
Wisconsin	5.6	5.5	5.4	5.3	5.2	5.1	33.1
Illinois	5.7	5.6	5.5	5.4	5.3	5.2	33.7
Indiana	5.8	5.7	5.6	5.5	5.4	5.3	34.3
Ohio	5.9	5.8	5.7	5.6	5.5	5.4	34.9
Michigan	6.0	5.9	5.8	5.7	5.6	5.5	35.5
Wisconsin	6.1	6.0	5.9	5.8	5.7	5.6	36.1
Illinois	6.2	6.1	6.0	5.9	5.8	5.7	36.7
Indiana	6.3	6.2	6.1	6.0	5.9	5.8	37.3
Ohio	6.4	6.3	6.2	6.1	6.0	5.9	37.9
Michigan	6.5	6.4	6.3	6.2	6.1	6.0	38.5
Wisconsin	6.6	6.5	6.4	6.3	6.2	6.1	39.1
Illinois	6.7	6.6	6.5	6.4	6.3	6.2	39.7
Indiana	6.8	6.7	6.6	6.5	6.4	6.3	40.3
Ohio	6.9	6.8	6.7	6.6	6.5	6.4	40.9
Michigan	7.0	6.9	6.8	6.7	6.6	6.5	41.5
Wisconsin	7.1	7.0	6.9	6.8	6.7	6.6	42.1
Illinois	7.2	7.1	7.0	6.9	6.8	6.7	42.7
Indiana	7.3	7.2	7.1	7.0	6.9	6.8	43.3
Ohio	7.4	7.3	7.2	7.1	7.0	6.9	43.9
Michigan	7.5	7.4	7.3	7.2	7.1	7.0	44.5
Wisconsin	7.6	7.5	7.4	7.3	7.2	7.1	45.1
Illinois	7.7	7.6	7.5	7.4	7.3	7.2	45.7
Indiana	7.8	7.7	7.6	7.5	7.4	7.3	46.3
Ohio	7.9	7.8	7.7	7.6	7.5	7.4	46.9
Michigan	8.0	7.9	7.8	7.7	7.6	7.5	47.5
Wisconsin	8.1	8.0	7.9	7.8	7.7	7.6	48.1
Illinois	8.2	8.1	8.0	7.9	7.8	7.7	48.7
Indiana	8.3	8.2	8.1	8.0	7.9	7.8	49.3
Ohio	8.4	8.3	8.2	8.1	8.0	7.9	49.9
Michigan	8.5	8.4	8.3	8.2	8.1	8.0	50.5
Wisconsin	8.6	8.5	8.4	8.3	8.2	8.1	51.1
Illinois	8.7	8.6	8.5	8.4	8.3	8.2	51.7
Indiana	8.8	8.7	8.6	8.5	8.4	8.3	52.3
Ohio	8.9	8.8	8.7	8.6	8.5	8.4	52.9
Michigan	9.0	8.9	8.8	8.7	8.6	8.5	53.5
Wisconsin	9.1	9.0	8.9	8.8	8.7	8.6	54.1
Illinois	9.2	9.1	9.0	8.9	8.8	8.7	54.7
Indiana	9.3	9.2	9.1	9.0	8.9	8.8	55.3
Ohio	9.4	9.3	9.2	9.1	9.0	8.9	55.9
Michigan	9.5	9.4	9.3	9.2	9.1	9.0	56.5
Wisconsin	9.6	9.5	9.4	9.3	9.2	9.1	57.1
Illinois	9.7	9.6	9.5	9.4	9.3	9.2	57.7
Indiana	9.8	9.7	9.6	9.5	9.4	9.3	58.3
Ohio	9.9	9.8	9.7	9.6	9.5	9.4	58.9
Michigan	10.0	9.9	9.8	9.7	9.6	9.5	59.5
Wisconsin	10.1	10.0	9.9	9.8	9.7	9.6	60.1
Illinois	10.2	10.1	10.0	9.9	9.8	9.7	60.7
Indiana	10.3	10.2	10.1	10.0	9.9	9.8	61.3
Ohio	10.4	10.3	10.2	10.1	10.0	9.9	61.9
Michigan	10.5	10.4	10.3	10.2	10.1	10.0	62.5
Wisconsin	10.6	10.5	10.4	10.3	10.2	10.1	63.1
Illinois	10.7	10.6	10.5	10.4	10.3	10.2	63.7
Indiana	10.8	10.7	10.6	10.5	10.4	10.3	64.3
Ohio	10.9	10.8	10.7	10.6	10.5	10.4	64.9
Michigan	11.0	10.9	10.8	10.7	10.6	10.5	65.5
Wisconsin	11.1	11.0	10.9	10.8	10.7	10.6	66.1
Illinois	11.2	11.1	11.0	10.9	10.8	10.7	66.7
Indiana	11.3	11.2	11.1	11.0	10.9	10.8	67.3
Ohio	11.4	11.3	11.2	11.1	11.0	10.9	67.9
Michigan	11.5	11.4	11.3	11.2	11.1	11.0	68.5
Wisconsin	11.6	11.5	11.4	11.3	11.2	11.1	69.1
Illinois	11.7	11.6	11.5	11.4	11.3	11.2	69.7
Indiana	11.8	11.7	11.6	11.5	11.4	11.3	70.3
Ohio	11.9	11.8	11.7	11.6	11.5	11.4	70.9
Michigan	12.0	11.9	11.8	11.7	11.6	11.5	71.5
Wisconsin	12.1	12.0	11.9	11.8	11.7	11.6	72.1
Illinois	12.2	12.1	12.0	11.9	11.8	11.7	72.7
Indiana	12.3	12.2	12.1	12.0	11.9	11.8	73.3
Ohio	12.4	12.3	12.2	12.1	12.0	11.9	73.9
Michigan	12.5	12.4	12.3	12.2	12.1	12.0	74.5
Wisconsin	12.6	12.5	12.4	12.3	12.2	12.1	75.1
Illinois	12.7	12.6	12.5	12.4	12.3	12.2	75.7
Indiana	12.8	12.7	12.6	12.5	12.4	12.3	76.3
Ohio	12.9	12.8	12.7	12.6	12.5	12.4	76.9
Michigan	13.0	12.9	12.8	12.7	12.6	12.5	77.5
Wisconsin	13.1	13.0	12.9	12.8	12.7	12.6	78.1
Illinois	13.2	13.1	13.0	12.9	12.8	12.7	78.7
Indiana	13.3	13.2	13.1	13.0	12.9	12.8	79.3
Ohio	13.4	13.3	13.2	13.1	13.0	12.9	79.9
Michigan	13.5	13.4	13.3	13.2	13.1	13.0	80.5
Wisconsin	13.6	13.5	13.4	13.3	13.2	13.1	81.1
Illinois	13.7	13.6	13.5	13.4	13.3	13.2	81.7
Indiana	13.8	13.7	13.6	13.5	13.4	13.3	82.3
Ohio	13.9	13.8	13.7	13.6	13.5	13.4	82.9
Michigan	14.0	13.9	13.8	13.7	13.6	13.5	83.5
Wisconsin	14.1	14.0	13.9	13.8	13.7	13.6	84.1
Illinois	14.2	14.1	14.0	13.9	13.8	13.7	84.7
Indiana	14.3	14.2	14.1	14.0	13.9	13.8	85.3
Ohio	14.4	14.3	14.2	14.1	14.0	13.9	85.9
Michigan	14.5	14.4	14.3	14.2	14.1	14.0	86.5
Wisconsin	14.6	14.5	14.4	14.3	14.2	14.1	87.1
Illinois	14.7	14.6	14.5	14.4	14.3	14.2	87.7
Indiana	14.8	14.7	14.6	14.5	14.4	14.3	88.3
Ohio	14.9	14.8	14.7	14.6	14.5	14.4	88.9
Michigan	15.0	14.9	14.8	14.7	14.6	14.5	89.5
Wisconsin	15.1	15.0	14.9	14.8	14.7	14.6	90.1
Illinois	15.2	15.1	15.0	14.9	14.8	14.7	90.7
Indiana	15.3	15.2	15.1	15.0	14.9	14.8	91.3
Ohio	15.4	15.3	15.2	15.1	15.0	14.9	91.9
Michigan	15.5	15.4	15.3	15.2	15.1	15.0	92.5
Wisconsin	15.6	15.5	15.4	15.3	15.2	15.1	93.1
Illinois	15.7	15.6	15.5	15.4	15.3	15.2	93.7
Indiana	15.8	15.7	15.6	15.5	15.4	15.3	94.3
Ohio	15.9	15.8	15.7	15.6	15.5	15.4	94.9
Michigan	16.0	15.9	15.8	15.7	15.6	15.5	95.5
Wisconsin	16.1	16.0	15.9	15.8	15.7	15.6	96.1
Illinois	16.2	16.1	16.0	15.9	15.8	15.7	96.7
Indiana	16.3	16.2	16.1	16.0	15.9	15.8	97.3
Ohio	16.4	16.3	16.2	16.1	16.0	15.9	97.9
Michigan	16.5	16.4	16.3	16.2	16.1	16.0	98.5
Wisconsin	16.6	16.5	16.4	16.3	16.2	16.1	99.1
Illinois	16.7	16.6	16.5	16.4	16.3	16.2	99.7
Indiana	16.8	16.7	16.6	16.5	16.4	16.3	100.3
Ohio	16.9	16.8	16.7	16.6	16.5	16.4	100.9
Michigan	17.0	16.9	16.8	16.7	16.6	16.5	101.5
Wisconsin	17.1	17.0	16.9	16.8	16.7	16.6	102.1
Illinois	17.2						

Loose Smut Reaction.

The method of seed inoculation discovered by Tisdale and Tapke (37) to induce infection with U. nuda was used in the present investigation. Complete failure of infection resulted. Tapke (34) has recently reported the occurrence of a new species of loose smut, Ustilago nigra, capable of producing seedling infection. The spores of this fungus are not only larger and darker in colour than those of U. nuda but retain their viability over a much longer period of time. Examination of the inoculum used in the present study, revealed spores typical of U. nuda. This ^{might} ~~would~~ explain the lack of infection reported above. Vanderwalle (38) showed the existence in loose smut of a particular late type which he considers to be intermediate between U. nuda and U. hordei.

It is apparent in the light of these recent findings that comparatively little is known regarding the etiology of the loose smut ^{disease} fungus. Further investigation in this regard is imperative if extensive breeding programmes for resistance to this disease are to be carried out.

The method of seed inoculation also varied by
Tisdale and Papke (37) to induce infection with U. ruga was
used in the present investigation. Complete failure of
infection resulted. Papke (34) has recently reported the
occurrence of a new species of loose smut, Helminthospora
capable of producing seedling infection. The spores of
this fungus are not only larger and darker in colour than
those of U. ruga but retain their visibility over a much
longer period of time. Examination of the inoculum used
in the present study, revealed spores typical of U. ruga.
This would explain the lack of infection reported above.
Vanderwall (38) showed the existence in loose smut of a
particular late type which he considers to be intermediate
between U. ruga and U. hordei.

It is apparent in the light of these recent find-
ings that comparatively little is known regarding the
etiology of the loose smut fungus. Further investigation
in this regard is imperative if extensive breeding pro-
grammes for resistance to this disease are to be carried

Stripe Reaction.

H. gramineum, the causal agent of the barley stripe disease, ~~does not readily produce conidia on artificial media.~~ is considered an obligate parasite, since few ~~for this reason, difficulty may be experienced in obtaining authentic records exist to show that it has produced conidia sufficient inoculum for extensive breeding tests on artificial media.~~ The disease has always been interesting because the pathogene was supposed to infect plants at flowering time and to cause a systemic infection similar to that of loose smut of wheat and barley. Several studies regarding the mode of infection of this fungus have modified the views in this regard.

Method of infection.

Ravn (28) concluded that H. gramineum, like certain smut fungi, inhabits the growing point of the host plant and thence spreads to each young part of the plant during the formation of that part. He found that the bulk of the infection occurred at flowering time and that low percentages of infection occurred when germinated seedlings were grown in the presence of mycelium.

Vogt (41) as a result of histological studies showed the mycelium inhabited the space between the glumes and the pericarp and is never found in the embryo or in the endosperm. Infection was found to take place through the coleoptile rather than the embryo.

Barley stripe

Barley stripe is caused by the causal agent of the barley stripe disease, *Helminthosporium sativum*, which is a fungus. It is a systemic infection and it causes a systemic infection similar to that of loose smut of wheat and barley. Several studies regarding the mode of infection of this fungus have modified the views in this regard.

Method of infection.

Ravn (28) concluded that *H. sativum* enters the growing point of the host plant and thence spreads to each young part of the plant during the formation of that part. He found that the bulk of the infection occurred at flowering time and that low percentages of infection occurred when germinated seedlings were grown in the presence of mycelium.

Voot (41) as a result of histological studies showed the mycelium inhabited the space between the glumes and the pericarp and is never found in the embryo or in the endosperm. Infection was found to take place through the coleoptile rather than the embryo.

Smith (32) came to similar conclusions in that he found infection to occur while the shoot is still under the adherent glumes or during its emergence. The inoculum was found to comprise, (a) conidia lodging at the awn end of the grain, (b) mycelium penetrating from the glumes and (c) perithecia formed inside or outside the glumes.

Johnson (23) showed that it was possible to obtain artificial infection of barley by simply inoculating the germinating kernels with spores or mycelia. Dehulling of the kernel increased the infection considerably.

In a later paper, Smith (33) showed definitely how infection of barley seedlings takes place. Mycelium is considered to be the main source of inoculum and is capable of living for at least two years in the chaff and pericarp. On the germination of the kernel the hyphae infect the primary sheaths, the coleorhiza (leading to root decay) and the coleoptile (causing leaf disease). From the coleoptile each successive leaf as formed is infected - the lesions on the newly infected leaf paralleling those on the older leaves enclosing it. The uppermost infected leaf may cause external infection of the young spike. Thus it can be seen that the mode of infection is contrary to that of smut infection. That is to say, the leaves are infected first and the growing point later, whereas, in the smuts the growing point is first infected and the other parts attacked as they are formed.

Smith (32) came to similar conclusions in that he found infection to occur while the shoot is still under the adjacent glumes or during its emergence. The inoculum was found to penetrate, (a) outside lodges at theawn end of the grain, (b) inoculum penetrating from the glumes and (c) perithecia formed inside or outside the glumes. Johnson (33) showed that it was possible to obtain artificial infection of barley by simply inoculating the germinating kernels with spores of *Ustilago*. Following of the kernel increased the infection considerably. In a later paper, Smith (34) showed definitely how infection of barley seedlings takes place. *Ustilago* is considered to be the main source of inoculum and is capable of living for at least two years in the chaff and pericarp. On the germination of the kernel the hyphae infect the primary sheath, the coleoptiles (leading to root decay) and the coleoptile (causing leaf disease). From the coleoptile each successive leaf as formed is infected - the lesions on the newly infected leaf parallel-ing those on the older leaves enclosing it. The uppermost infected leaf may cause external infection of the young spike. Thus it can be seen that the mode of infection is contrary to that of smut infection. That is to say, the leaves are infected first and the growing point later, whereas, in the smuts the growing point is first infected and the other parts attacked as they are formed.

Temperature relationships.

Several investigators have demonstrated that low soil temperatures favour infection of barley seedlings with H. gramineum.

Ravn (28) found that early planting produced greater infection. Johnson (23) showed, by the use of controlled experiments, that low soil temperatures are favourable to increased infections. He found ^{the} optimum temperature to be 10 - 12 ° C., while little occurred at soil temperatures higher than 20° C. Smith (33) points out that low soil temperatures greatly slow down germination processes, thus increasing the likelihood of infection while the shoot is still confined within the chaff. It has been noticed that barley growers in ^{western Canada} ~~the West~~ are troubled very little with damage from the stripe disease, whereas, considerable injury occurs in the barley plots at the experimental stations. The probable explanation, is that, in view of the fact that barley is generally seeded much later in ordinary farming practice than it is at the experimental stations, the high temperatures inhibit development of the fungus.

In the present study the inoculated kernels were planted as early in the spring of 1932 as was deemed practible, with soil temperatures ranging about 50°-55° F.

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1. Introduction

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In the present study the inoculated kernels were planted as early in the spring of 1932 as was deemed practicable.

Physiologic specialization.

Physiologic specialization in this fungus was first demonstrated by Johnson (23). A single spore isolation obtained from Edmonton, Alberta, failed to recover when kept at 32° - 33° C. for 10-12 days, while several other cultures tested in a similar manner recovered and grew normally. This form also grew better at 5 - 6° C. than did the other cultures under test.

Christensen and Graham (4) found 84 culturally distinct forms on testing 226 monosporous cultures obtained from United States, Canada and Germany. The pathogenicity of 75 races tested on several varieties of barley showed additional evidences of specialization.

Isenbeck (22) reports that American forms of this fungus were less virulent than the German. Differences in pathogenicity of the forms were noted.

Inoculation methods.

It has been shown that the source of primary infection is the presence of mycelium (or conidia) either in the pericarp or lodged between the pericarp and kernel. Mention has been made that Ravn (28) obtained good infection by floral inoculation of barley plants, while high infections were obtained by Johnson (23) when dehulled germinating kernels were inoculated with either the spores or mycelia. The period of greatest susceptibility in dehulled kernels, according to Johnson, appeared to be just subsequent to the emergence of the coleoptile.

Physiological specialization

Physiological specialization in this fungus was first demonstrated by Johnson (23). A single spore inoculation obtained from Edmonton, Alberta, failed to recover when kept at 22-25° C. for 10-12 days, while several other cultures tested in a similar manner recovered and grew normally. This form also grew better at 2-5° C. than did the majority of other isolates.

Christensen and Graham (1) found 84 culturally distinct forms on testing 288 monospore cultures obtained from United States, Canada and Germany. The pathogenicity of 75 races tested on several varieties of barley showed additional evidences of specialization.

Johnson (23) reports that isolates from the same source were less virulent than the German. Differences in pathogenicity of the same source were

Pathogenicity

It has been shown that the source of primary infection is the presence of mycelium (or conidia) either in the pericarp or lodged between the pericarp and kernel. Mention has been made that Rehn (26) obtained good infection by floral inoculation of barley plants, while high infections were obtained by Johnson (23) when debilled germinating kernels were inoculated with either the spores or mycelia. The period of greatest susceptibility in debilled kernels, according to Johnson, appeared to be just subsequent

Genau (11) found the optimum time to ^{circulate to} effect floral ~~inoculation~~ ^{infection} with conidial suspension was the day following opening, provided the temperature approximated 25° C. Young seedlings 1-2 cm. in height were found to be readily infected by means of a conidial suspension in sufficiently warm and humid atmospheres. In one experiment the plants were successfully inoculated with the ascospores of the fungus.

Fuchs (10) has devised a method of artificial inoculation consisting of the injection of a conidial suspension of the fungus into the ripe grain after soaking the latter for an hour or two in water so as to loosen the glumes from the grain and permit of inserting the needle between them. For large quantities of inoculum a modified method was devised. The barley grains were placed in a vacuum for 20 minutes in a conidial suspension in such a way that the air between the glumes and seed is removed. When the pressure is restored the conidial suspension penetrates with great impetus between the glume and the caryopsis. To stimulate abundant mycelial production, the inoculated grains are placed in an incubator at temperatures of 25°C.-28°C. and at an atmospheric humidity of 90-100%. It is claimed that this method gave results in complete agreement with the floral method used by Genau(11).

Isenbeck (22) in a breeding study used methods of wet and dry flower infections, seedling infection and grain infection with spores or mycelia.

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Trachs (10) has devised a method of artificial
inoculation consisting of the infection of a conidia sus-
pension of the fungus into the ripe grain either soaking the
latter for an hour or two in water so as to loosen the
glumes from the grain and permit of inserting the needle
between them. For large quantities of inoculum a modified
method was devised. The barley grains were placed in a
vacuum for 30 minutes in a conidia suspension in such a way
that the air between the glumes and seed is removed. When
the pressure is restored the conidia suspension penetrates
with great impetus between the glume and the carpels.
To stimulate abundant mycelial production, the inoculated
grains are placed in an incubator at temperatures of 25° C.-
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claimed that this method gave results in complete agreement
with the floral method used by Genes (11).
Isenbeck (22) in a breeding study used methods
of wet and dry flower infections, seedling infection and
grain infection with spores or mycelia.

A method of floral inoculation, using a wet conidial suspension, was utilized in the present work. The inoculum consisted, in the main, of ^{spore from} diseased leaves from plants of a badly infected plot of Canadian Thorpe; this was supplemented from time to time by a composite sample of inoculum from the varietal plots. The infected leaves were placed in an incubating chamber over night to stimulate spore production. The following day the leaves were rubbed together under water until nothing but a pulp remained of them. The spore suspension was then strained through three layers of cheese-cloth to remove all suspended vegetative matter. Two heads from approximately 500 F_2 plants of crosses involving Trebi and Glabron, as well as two heads of 100 parental plants were selected at random for inoculation. This consisted of simply soaking the spikes with the solution and immediately enclosing them in a glassine bag. The heads were given additional sprays at four to five day intervals by means of an atomizer, the nozzle of the latter being inserted through a slit cut in the glassine bag. The weak straw of the barley plant caused considerable difficulty in that it was necessary to support the majority of the bagged spikes. Even with this precaution a number of spikes were broken over by the wind and rain.

A method of floral inoculation, using a wet chamber, was utilized in the present work. The inoculum consisted, in the main, of diseased leaves from plants of a badly infected plot at Canadian Forces; this was removed from time to time by a composite sample of inoculum from the veretial plots. The infected leaves were placed in an incubating chamber over night to stimulate spore production. The following day the leaves were rubbed together under water until nothing but a pulp remained of them. The spore suspension was then strained through three layers of cheese-cloth to remove all suspended vegetative matter. Two heads from approximately 500 F₂ plants of crosses involving Trebi and Gibson, as well as two heads of 100 parental plants were selected at random for inoculation. This consisted of simply soaking the spikes with the solution and immediately enclosing them in a glassine bag. The heads were given additional sprays at four to five day intervals by means of an atomizer, the nozzle of the latter being inserted through a slit cut in the glassine bag. The weak straw of the barley plant caused considerable difficulty in that it was necessary to support the majority of the bagged spikes. Even with this precaution a number of spikes were broken over by the wind and rain.

Genetic studies.

The only work to appear in the literature regarding the inheritance of reaction of barley to H. gramineum is that reported by Isenbeck (22). The progeny of 8 crosses with different combinations of immunity, resistance and susceptibility in the parents were studied. The F_2 flowers were inoculated thus giving ratios for the F_3 . The F_4 was also studied in some cases. All the crosses were tested by the method of wet infection, two by dry infection and one F_3 was also tested in the greenhouse by the infection of the grain. Generally immunity was found to be dominant; crosses between two immune varieties gave no susceptibles, whereas crosses between two resistant types resulted in some susceptible types. Transgression also occurred when two susceptibles were crossed. The results can be only explained by assuming a large number of factors.

It has already been stated that the inoculated seeds of the present investigation were seeded as early as possible to take advantage of the low prevailing soil temperatures. The infected plants showed characteristic symptoms of the disease; these showing up strikingly just prior to heading. Little or no partial infection occurred, the plants being ruined economically (Figure VIII). The infection classes, in percentage, for the parental rows and hybrid lines are given in Table XXII.

The only work to appear in the literature regard-
ing the inheritance of resistance of barley to *H. graminum*
is that reported by Isenback (1931). The progeny of 8 crosses
with different combinations of immunity, resistance and
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hybrid lines are given in Table XXII.



FIGURE VIII.

Barley plants infected with stripe, Helminthosporium gramineum. Normal plant in the centre.

(Photograph taken when normal plants were approaching maturity).

TABLE XXII.

Reaction of F_3 lines and parental varieties to
H. gramineum in reciprocal crosses of
Glabron and Trebi.

Cross or parent	Infection classes in percentage.									
	0	2.5	7.5	12.5	17.5	22.5	27.5	32.5	57.5	
Trebi	39	8								
Glabron		8	14	12	7	5	1			
126 lines										
Glabron x Trebi	36	40	31	13	3	-	1	1	1	
336 lines										
Trebi x Glabron	137	93	48	20	11	5	1	-	-	
Total 462 lines	173	133	79	33	14	5	2	1	1	

The Trebi parent appears to be highly resistant to the form of the pathogene H. gramineum used, while Glabron shows infection varying from 2.5 percent to 27.5 percent; with greatest number of lines showing from 7.5 to 12.5 percent infection. This wide range of infection percent exhibited by Glabron would indicate certain limitations in the inoculation methods employed. There is no evidence of any transgression toward greater susceptibility in the hybrids except in one line, which gave 57.5 percent infection. No particular significance can be attached to this line since there is no evidence that it did not result from an admixture. Isenbeck (22) found that the number of resistant individuals in the progeny increased with the degree of resistance of the two parents. The present results bear out this conclusion. Keeping the parental types

Reaction of T₁ lines and parental varieties to
H. graminum in response to various
 treatments and methods.

Infection always in percentage									
Cross or									
185 lines	36	40	31	18	3	7	5	1	1
Glendon x Trest									
330 lines	187	38	48	20	11	5	1	1	1
Trest x Glendon									
Total 485 lines	173	138	79	38	14	5	2	1	1

The Trest parent appears to be highly resistant to the form of the pathogen H. graminum used, while Glendon shows infection varying from 2.5 percent to 27.5 percent; with greatest range of lines showing from 7.5 to 12.5 percent infection. This wide range of infection percent exhibited by Glendon would indicate certain limitations in the inoculation methods employed. There is no evidence of any transgression toward greater susceptibility in the hybrids except in one line, which gave 27.5 percent infection. No particular significance can be attached to this line since there is no evidence that it did not result from an admixture. Isenbeck (22) found that the number of resistant individuals in the progeny increased with the degree of resistance of the two parents. The present results bear out this conclusion. Keeping the parental types

in view it is extremely difficult to postulate any definite mode of inheritance. It is important to point out, at this time, that the plants selected in the F_2 for inoculation were really a random distribution of the early plants, since there had been a tendency to select early plants for inoculation purposes. Whether or not this factor would have any effect on the percentage of infection obtained is open to question. Isenbeck (22) found that the early varieties tended to be more susceptible than the late.

The writer would like to suggest at this time that some method other than floral inoculation should be utilized if uniform results, so important to inheritance studies, are to be obtained. The element of chance plays such an important role in this type of inoculation that there is no certainty as to what percentage of the kernels of a spike will be successfully infected. Even the excellent precaution of bagging the heads, has a very decided weakness, in that the barley peduncle is not sufficiently strong to support these bags under any type of adverse conditions. It is doubtful whether the mycelium of the fungus develops normally on the spikelets of broken-over heads. Some method of inoculating the seedling or the mature kernel as pointed out by Genau (11) and Fuchs (10) seems more promising. Isenbeck (22) claims that for ordinary purposes and varietal trials, field infection was preferable, but for inheritance tests the greenhouse infection was better, in that it gave a more uniform and severe infection.

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CORRELATION STUDIES.

General

The importance of correlation studies cannot be over estimated when used in connection with the inheritance of disease reaction. This type of inheritance does not lend itself readily to factorial analysis, and it is only through establishing certain associations between the factors concerned in resistance and susceptibility, with those of some easily distinguishable morphological character, that it is possible to determine the number of factors concerned in a given disease reaction.

Griffie demonstrated in a striking manner the value of such linkage studies. He was able to show, by studying the reaction of F_3 lines to H. sativum in relation to three other independently inherited characters, that at least three factors were concerned in a certain type of resistance.

Characters correlated.

In this paper correlations were calculated between the different characters studied earlier. Since the data of all the characters, with the exception of barbing of awn, were in definite numerical classes, it was possible to use the correlation coefficient in the majority of cases.

RESULTS

1. Inheritance

a. Disease reaction

The importance of correlation studies cannot be over estimated when used in connection with the inheritance of disease reaction. This type of inheritance does not lend itself readily to factorial analysis, and it is only through establishing certain associations between the factors concerned in resistance and susceptibility, with those of some easily distinguishable morphological character, that it is possible to determine the number of factors concerned in a given disease reaction.

Griffes demonstrated in a striking manner the value of such linkage studies. He was able to show, by studying the reaction of T_3 lines to H. sativae, in relation to three other independently inherited characters, that at least three factors were concerned in a certain type of resistance.

2. Correlation

In this paper correlations were calculated between different characters studied earlier. Since the data were obtained with the exception of bending of stem, it was possible to use definite numerical classes, it was possible to use

Whenever the character of barbing of awn was involved, the correlation ratio was employed. Probable errors were computed by standard formulae (3,19).

The data in Table XXIII show a summary of the correlation values derived in the course of the inheritance studies just reported.

It will be seen that, with the exception of three, (marked by asterisks), the correlation values are significant in the light of their probable errors. High correlations exist between height and number of days to heading. It has already been explained in connection with inheritance studies on plant height, that, although this association may be partially explained on a physiological basis, its high value would suggest that certain genetic factors, responsible for earliness of heading, are also responsible for height of plant. Positive correlations exist between covered smut reaction and both mean number of days to heading and mean height of plant. These associations may also be explained on a physiological basis. The later lines allow for a more optimum development of the pathogene, and since height of plant and number of days to heading are highly correlated, the tall plants tend to show greater susceptibility. It should be remembered that height of plant entered the cross together with resistance to covered smut disease, hence no genetic linkage can be said to exist.

Whenever the character of barbing of awn was favourable, the

by standard formulae (8, 19).

The data in Table XVII show a summary of the

correlation values derived in the course of the inheritance

studies just reported.

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earliness of heading, are also responsible for height of

plant. Positive correlations exist between covered and

resistance and both mean number of days to heading and mean

height of plant. These associations may also be explained

on a physiological basis. The latter lines allow for a more

optimum development of the pathogen, and since height of

plant and number of days to heading are highly correlated,

the tall plants tend to show greater susceptibility. It

should be remembered that height of plant entered the cross

together with resistance to covered and disease, hence no

can be said to exist.

TABLE XXIII.

Correlation of characters in the F₃ hybrids of reciprocal crosses between Glabr³ and Trebi.

Character and reaction correlated	F ₃ hybrids	Correlation coefficient	Correlation ratio
		r	q
Mean height and mean number of days to heading	Cross 12	0.728 ₊ .025	
	Cross 21	0.737 ₊ .030	
Mean height and stripe infection	Cross 12 & 21	0.388 ₊ .112	
Mean height and covered smut infection	Cross 12	0.266 ₊ .060	
	Cross 21	0.498 ₊ 0.65	
Mean number of days to heading and stripe infection	Cross 12 & 21	0.124 ₊ .130*	
Mean number of days to heading and covered smut infection	Cross 12	0.193 ₊ .059	
	Cross 21	0.366 ₊ .075	
Barbing of awn and mean height	Cross 12		0.211 ₊ .051
	Cross 21		0.084 ₊ .065*
Barbing of awn and stripe infection	Cross 12 & 21		0.292 ₊ .091
Barbing of awn and covered smut infection	Cross 12		.030 ₊ .043*
	21 & 45		

* Correlation values not significant.

TABLE III

Correlation of characters in the F₂ hybrids of
Phaseolus vulgaris L. var. *Stout*.

Character and notation	F ₂ hybrids	Correlation coefficient	Normal deviation
Mean height and mean number of days to heading	Gross 13	-0.788±.085	
Mean height and stripe infection	Gross 21	-0.707±.070	
Mean height and covered and smut infection	Gross 13 & 21	-1.008±.118	
Mean number of days to heading and stripe infection	Gross 13	-0.886±.080	
Mean number of days to heading and covered and smut infection	Gross 21	-0.488±.0.35	
Mean number of days to heading and covered and smut infection	Gross 13 & 21	-0.184±.180	
Barbing of awn and stripe infection	Gross 13	-0.193±.089	
Barbing of awn and stripe infection	Gross 21	-0.884±.078	
Barbing of awn and covered and smut infection	Gross 13 & 21	-0.201±.070	
Barbing of awn and covered and smut infection	Gross 13	-0.284±.078	
Barbing of awn and covered and smut infection	Gross 21	-0.201±.070	
Barbing of awn and covered and smut infection	Gross 13 & 21	-0.284±.078	

Small positive correlations exist between the different combinations of stripe reaction, height of plant and smoothness of awn. Since smooth awn entered the cross, with height and resistance to the stripe disease, slight genetic linkages may be indicated. The low values of η obtained between barbing of awn and both plant height and reaction to the stripe disease render these associations very uncertain as to their statistical significance.

No significant correlations existed between mean number of days to heading and stripe infection; barbing of awns and covered smut infection, and between barbing of awn and mean height (one cross only).

ECONOMIC SIGNIFICANCE.

Selections from the F_3 hybrid lines were made on the basis of barbing of awn, disease resistance, earliness of plant, ^{maturity} and strength of straw. Approximately 350 smooth-awned plant selections have been prepared for further testing in the F_4 . In addition, seven homozygous F_3 smooth awned lines have been bulked for immediate row-yield tests.

Small positive correlations exist between the different combinations of stripe resistance, height of plant and smoothness of awn. Since smooth awn entered the cross, with height and resistance to the stripe disease, slight genetic linkages may be indicated. The low values of r obtained between heading of awn and both plant height and resistance to the stripe disease render these associations very uncertain as to their statistical significance. No significant correlations existed between mean number of days to heading and stripe infection; heading of awn and covered smut infection, and between heading of awn and mean height (one cross only).

GENETIC CORRELATIONS

Selections from the F_2 hybrid lines were made on the basis of heading of awn, disease resistance, earliness of plant and strength of straw. Approximately 350 smooth-awned plant selections have been prepared for further testing in the F_4 . In addition, seven homozygous T_2 smooth-awned lines have been bulked for immediate row-row yield tests.

SUMMARY.

1. Reciprocal crosses between Glabron and Trebi have been used to determine the inheritance of the following character pairs: Rough vs. smooth awn, long- vs. short-haired rachilla, early vs. late heading, tall vs. short and resistance vs. susceptibility to both U. hordei and H. gramineum. The character pair, rough vs. smooth awn was studied in the F_1 , F_2 and F_3 ; the character pair long- vs. short-haired rachilla in the F_2 and the remaining character pairs in the F_3 .

Studies on barbing of awn were also made in the F_2 of crosses involving Velvet and Trebi.

2. F_2 and F_3 studies showed the rough awned condition to be governed by two factors, which may be explained on the basis of epistasis. The factor R produces rough awn, while the factor S is hypostatic to R, and in the absence of R, produces the intermediate-smooth awn. The double recessive rrss produces the smooth awn. The phenotypes rough, intermediate-smooth and smooth were obtained in a 12:3:1 ratio in the F_2 . The homozygous intermediate-smooth plants rrSS exhibited a stronger degree of barbing than did the heterozygous plants rrSs.

3. The factor pair long- vs. short-haired rachilla was shown to be inherited in a simple Mendelian manner.

RESULTS

1. Reciprocal crosses between *flabron* and *trid* have

been used to determine the inheritance of the following

characters: *flabron* vs. *trid*, *flabron* vs. *flabron*, *trid* vs. *trid*.

ed rachilla, early vs. late heading, tall vs. short and

resistance vs. susceptibility to both *U. horrida* and *U. crassa*.

flabron. The character pair, rough vs. smooth was studied

in the F_1 , F_2 and F_3 ; the character pair long vs. short

in the F_1 , F_2 and the remaining character pairs

in the F_3 .

Studies on heading of ears were also made in the F_1

of crosses involving *Velvet* and *Trid*.

2. F_1 and F_2 studies showed the rough smooth condition

to be governed by two factors, which may be explained on the

basis of epistasis. The factor R produces rough ears, while

the factor S is hypostatic to R, and in the absence of R,

produces the intermediate-smooth ears. The double recessive

ears produces the smooth ears. The phenotypes rough, intermediate

smooth and smooth were obtained in a 12:3:1 ratio in the F_2 .

The homozygous intermediate-smooth plants were selected a

stronger degree of heading than did the heterozygous plants

these.

3. The factor pair long vs. short-haired rachilla

was shown to be inherited in a simple Mendelian manner.

4. A linkage was obtained between the factor pair responsible for rachilla hair length and the main factor pair for barbing of awn, the cross over value being 33.4 ± 1.7 per cent.

5. Two main complementary factors were found to be involved in earliness of heading. There was a suggestion that a third factor pair might be operative.

6. The number of factors concerned in the inheritance of height is not clear. Parental forms were recovered and cumulative factors are indicated.

7. Kernels of parental and hybrid lines dehulled with concentrated sulphuric acid to induce greater covered smut infection, gave greatly reduced germination. Treating of severely threshed kernels was found to seriously impair the germination of such seeds. Many weakened seedlings resulting from acid-dehulled kernels were predisposed to attack by certain blue mould fungi. The greater opportunity of infection afforded the pathogene, resulted in great distortion of the seedlings, accompanied by failure to reach the soil surface.

8. No genetic hypothesis can be advanced for the inheritance of reaction to U. hordei. The Glabron parent showed relatively high resistance to the form of the pathogene used, while Trebi appeared to be moderately susceptible. Considerable variability existed in the infection percentages

4. A linkage was obtained between the factor pair responsible for rachilla hair length and the main factor pair for heading of ear, the cross over value being 33.4+1.7 per cent.

5. Two main complementary factors were found to be involved in earliness of heading. There was a suggestion that a third factor pair might be operative.

6. The number of factors concerned in the inheritance of height is not clear. Parental forms were recovered and cumulative factors are indicated.

7. Kernels of parental and hybrid lines deficient with concentrated sulphuric acid to induce greater covered and infection, gave greatly reduced germination. Treating of severely threshed kernels was found to seriously impair the germination of such seeds. Many weakened seedlings resulting from acid-damaged kernels were predisposed to attack by certain blue mould fungi. The greater opportunity of infection afforded the pathogen, resulted in great distortion of the seedlings, accompanied by failure to reach the soil.

8. No genetic hypothesis can be advanced for the inheritance of reaction to H. hordei. The Clapton parent showed relatively high resistance to the form of the pathogen used, while Trest appeared to be moderately susceptible. H. hordei virulence existed in the infection percentages.

of the Trebi parent. The resistance exhibited by the parents was reflected in the progeny, no transgressive segregation for greater susceptibility occurring.

9. No infection with U. nuda resulted when a method of seed inoculation was used.

10. A method of wet floral inoculation was used to induce infection with H. gramineum. Only the heads of the F_2 plants were inoculated, thus giving ratios for the F_3 . The Trebi parent proved to be resistant, and the Glabron parent moderately resistant to the form of the pathogene used. The wide range of infection percentages exhibited by the Glabron parent indicated certain limitations in the inoculation methods employed. The progeny showed little evidence of transgressive segregation for greater susceptibility. Keeping parental types in mind, it is difficult to postulate any definite mode of inheritance of resistance to H. gramineum in the hybrids tested.

11. A high correlation was found to exist between height of plant and number of days to heading. A segregation for physiological factors would probably explain this association. Moderate degrees of association were found to exist between covered smut reaction and both number of days to heading and height of plant. Slight correlations existed between the different combinations of height of plant, barbing of awn and stripe disease reaction. No significant

of the parent. The resistance exhibited by the parent was reflected in the progeny, no transgressive segregation for greater susceptibility occurring.

9. No infection with H. tritici resulted when a method of seed inoculation was used.

10. A method of wet flannel inoculation was used to induce infection with H. tritici. Only the heads of the plants were inoculated, thus giving ratios for the parent moderately resistant to the form of the pathogen used. The wide range of infection percentages exhibited by the elabon parent indicated certain limitations in the inoculation methods employed. The progeny showed little evidence of transgressive segregation for greater susceptibility. Keeping parental types in mind, it is difficult to postulate any definite mode of inheritance of resistance to H. tritici in the hybrids tested.

11. A list of characters was made of the parents, height of plant and number of days to heading. A suggestion for physiological factors would probably explain this association. Moderate degrees of association were found to exist between covered and open panicle and both number of spikes per ear and number of grains per spike. It is suggested that the different combinations of height of

correlations were found between stripe infection and number of days to heading; barbing of awn and covered smut reaction and between barbing of awn and mean height (one cross only).

12. A large number of smooth awned disease resistant lines of desirable agronomic types have been selected for further study. Also, seven homozygous smooth awned lines have been bulked for yield tests.

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conclusions were found between various factors and changes in days in feeding; feeding at one and another hour resulted in different feeding of one and same weight (one given only).

22. A large number of reports on the effects of feeding of variously composed types have been collected for further study. Also, even homologous reports have been collected and been pulled for whole books.

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